



Bentley RM Bridge Introducing CAST Tool

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Technical Support Analyst



Bentley RM Bridge CAST Tool

- Skill Level: Beginner
- Presenter: Marcos Beier, Bentley
 - Balance Cantilever Concrete
 - Segmental & Post Tensioned
 - Integrated control of the match:

RM CAST



RM Bridge CAST tool

1. Balance Cantilever
2. RM Bridge *Solutions*
3. CAST tool



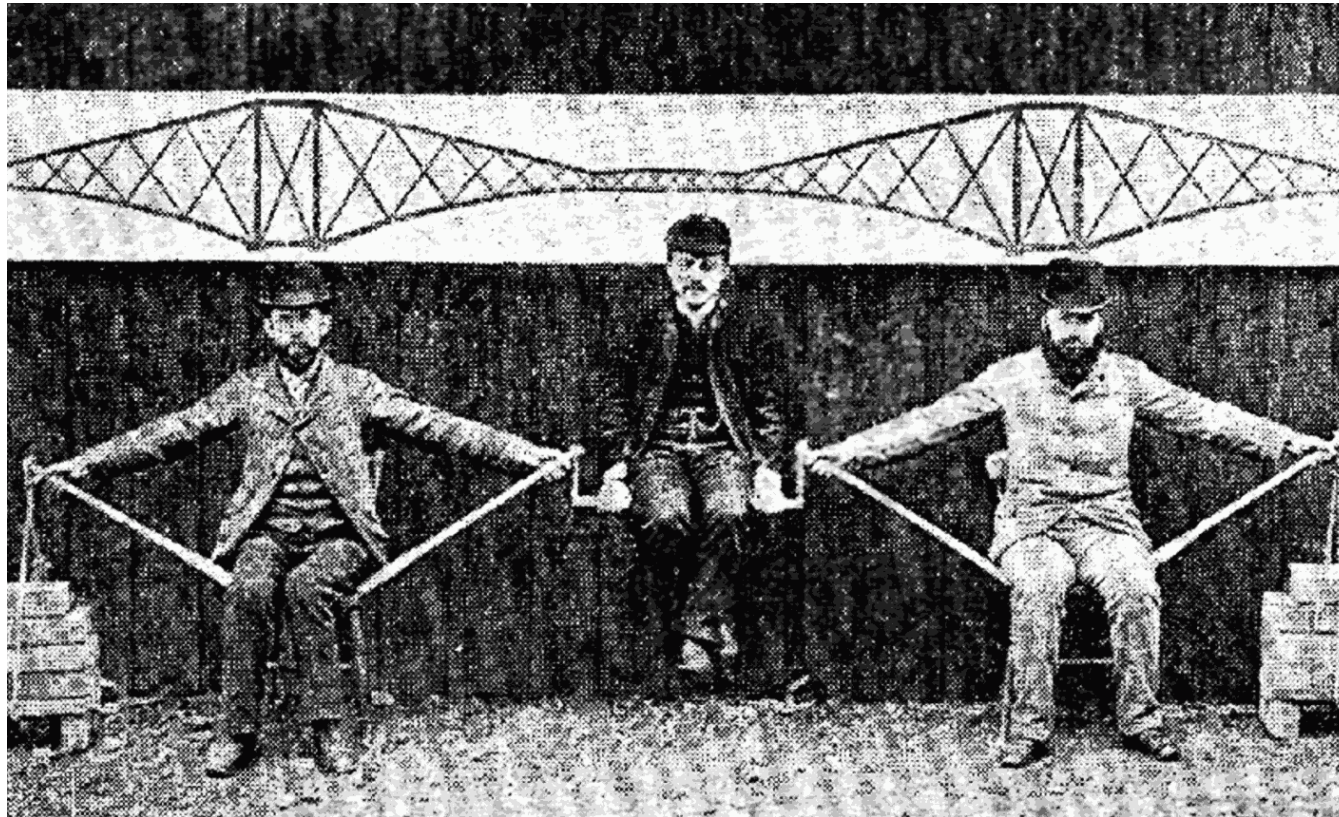
Balance Cantilever

Segmental precast



Balance Cantilever

China A.C.



Central span suspension

UK “demo”

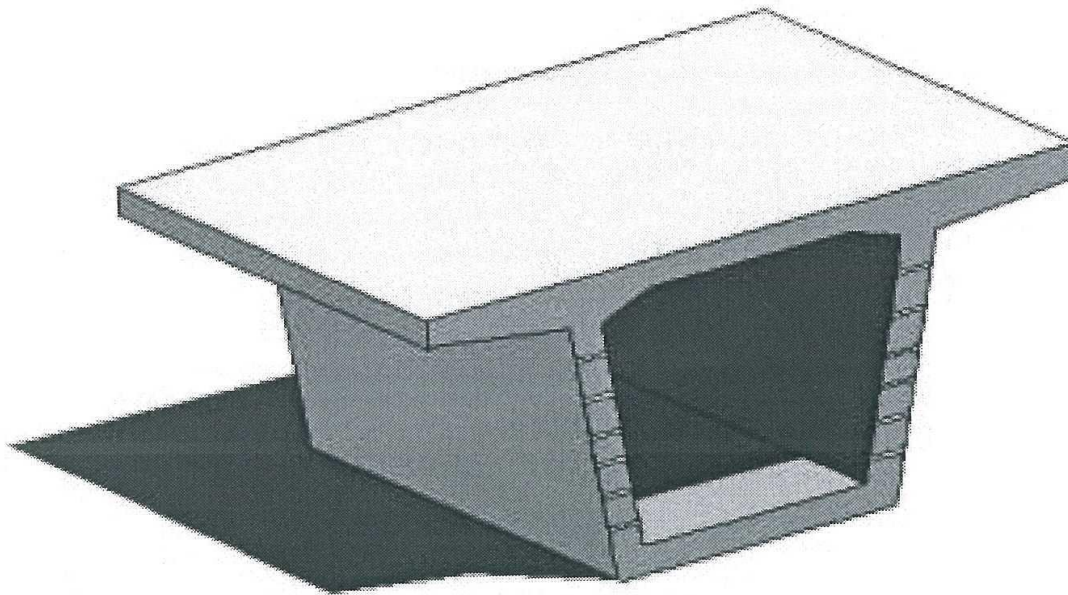


Pre-Cast Balance Cantilever

Fort Lauderdale

Motivation

- Advantages of Pre-casting:
 - Better quality due to production in controlled environment
 - Less formwork needed
 - Less invasive (disturbance of traffic, environmental, ...)
 - Accelerated construction time

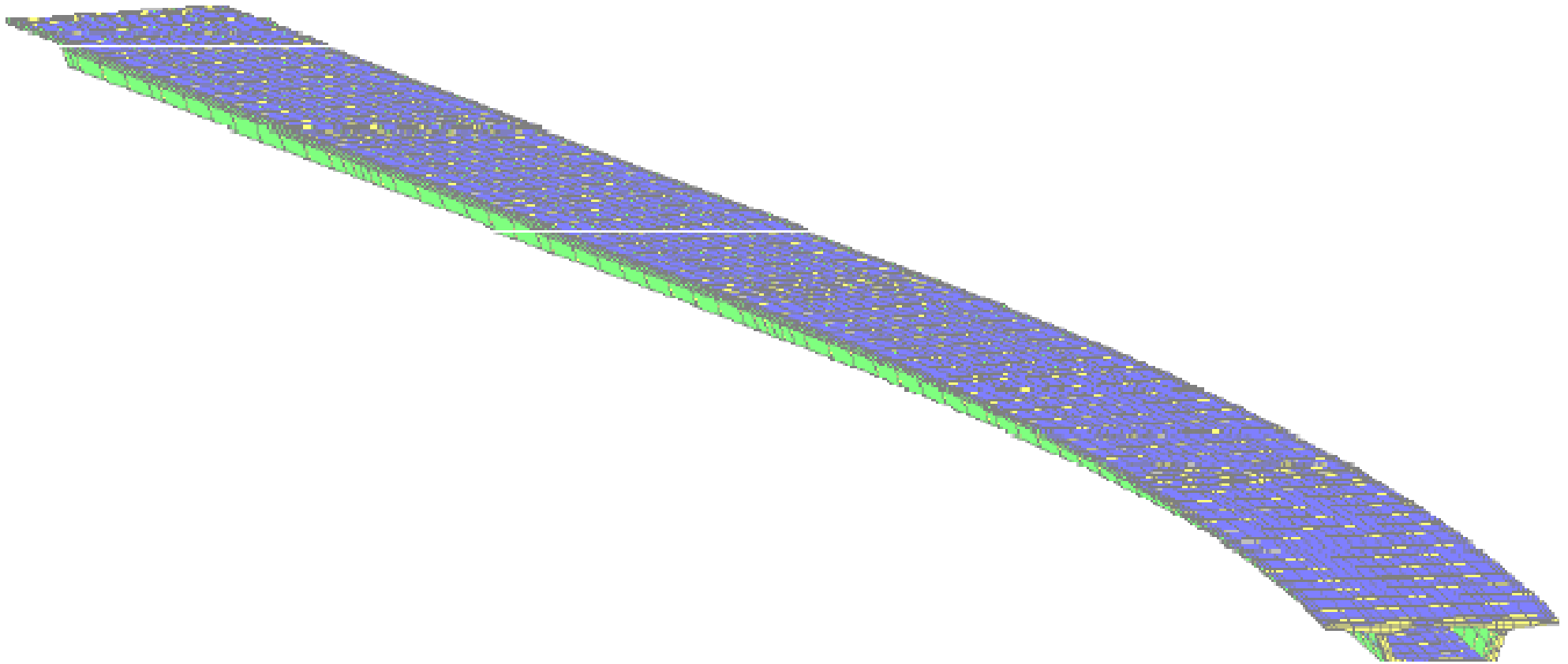




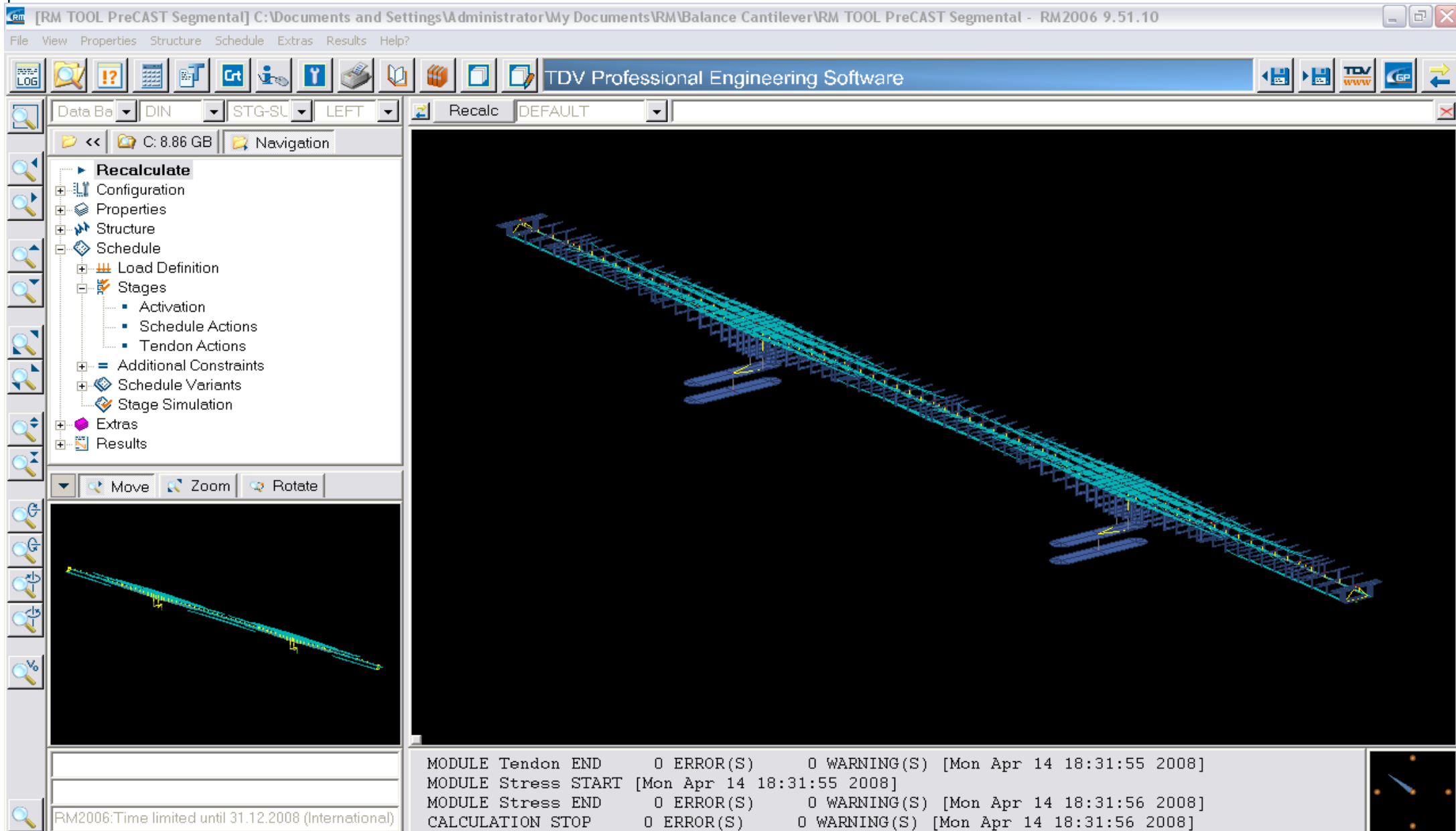
Precast Segment

Pier table segment

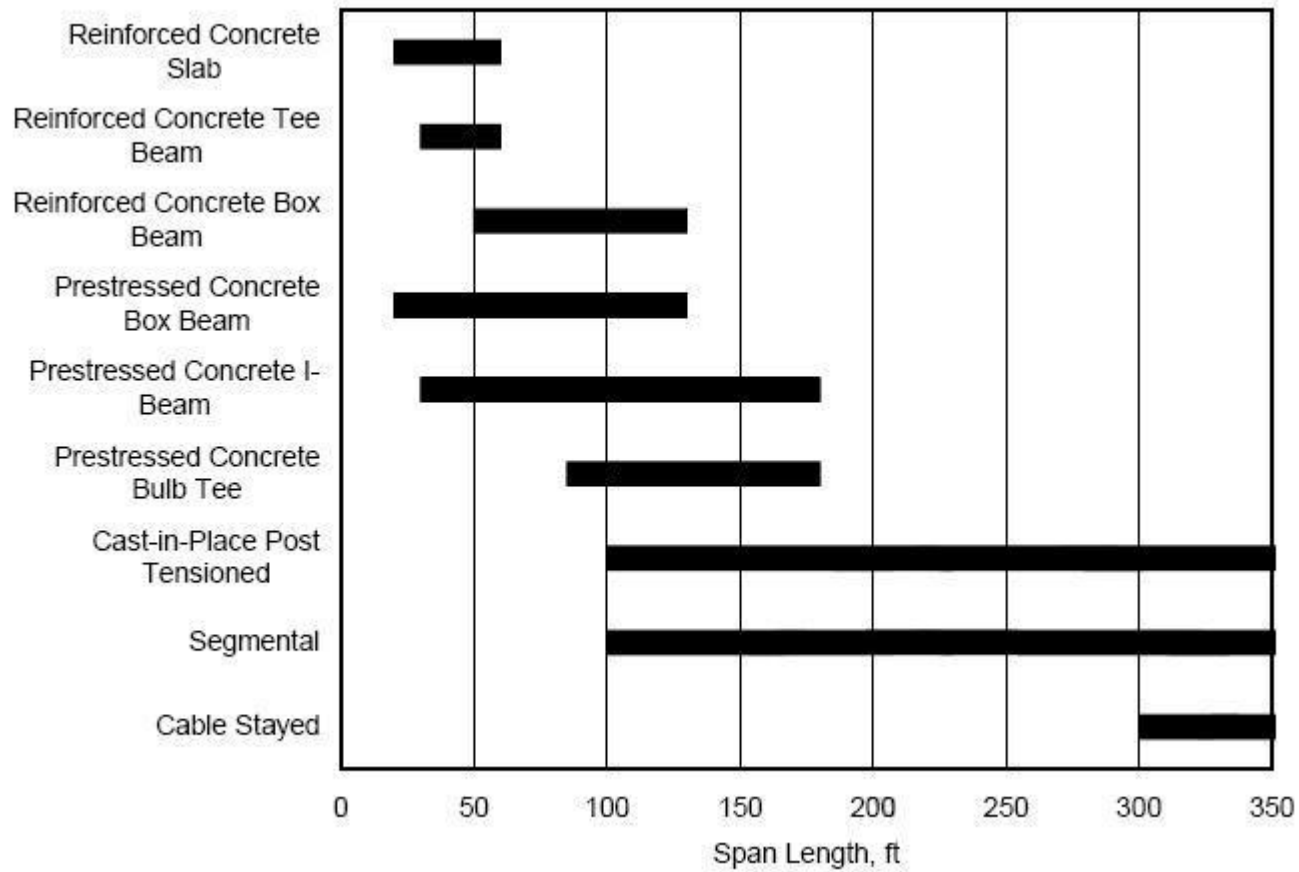
Bentley Bridge RM – GP



13



TS&L



RM Bridge

Problems we face and Solutions we provide

Segmental BCB in Bentley RM Bridge

Problems we face

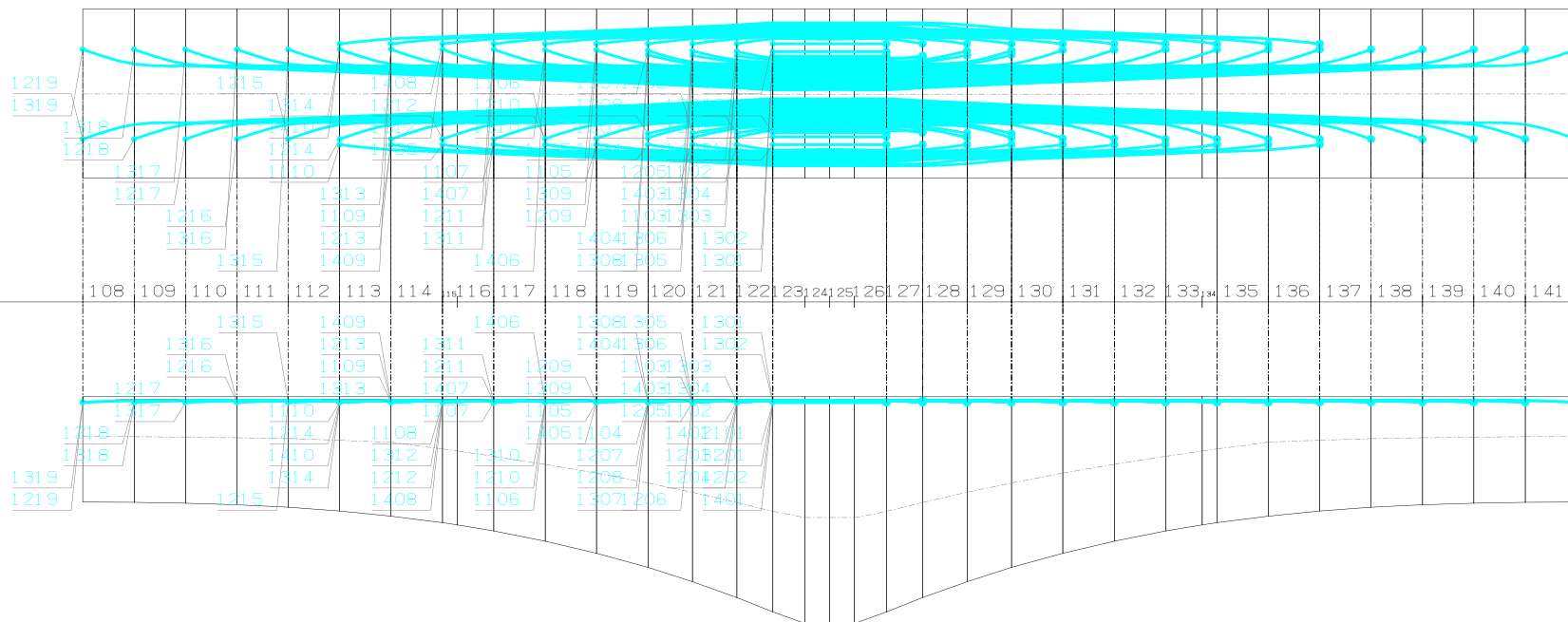
- PT
- C&S
- Camber
- Optimal Solution?
- Onsite control
- Precast factory control

Solutions we provide

- Cantilever Tool
- Pre-camber
- ADDCON
- Cast TOOL
- Erection Control

RM Bridge Cantilever TOOL

Plan



Elevation



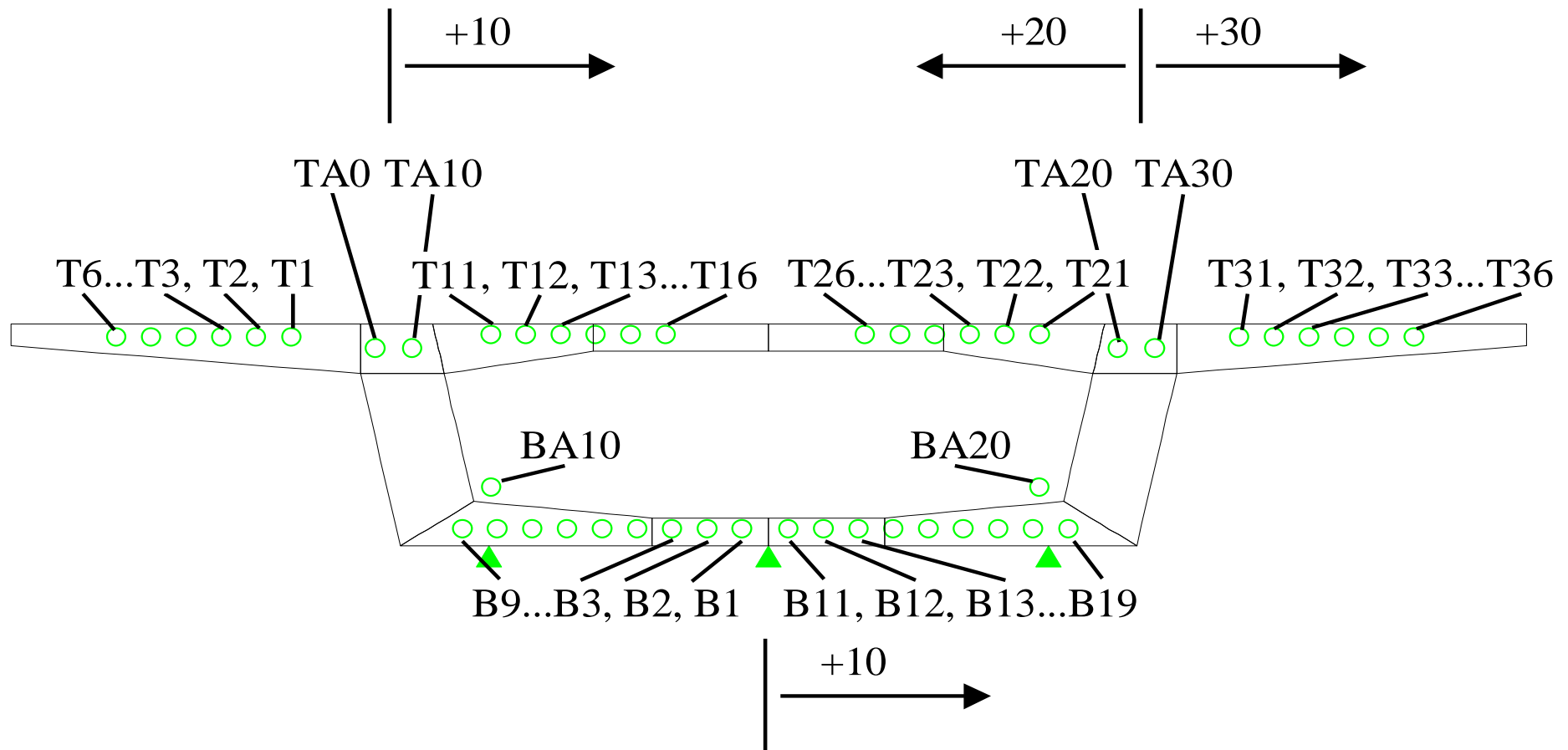
Author: Ace Sistemas - TDV software representative -
Av. Sao Pedro, 1001/303, CEP 90250-121 PORTO ALEGRE/RS BRAZIL

Project:

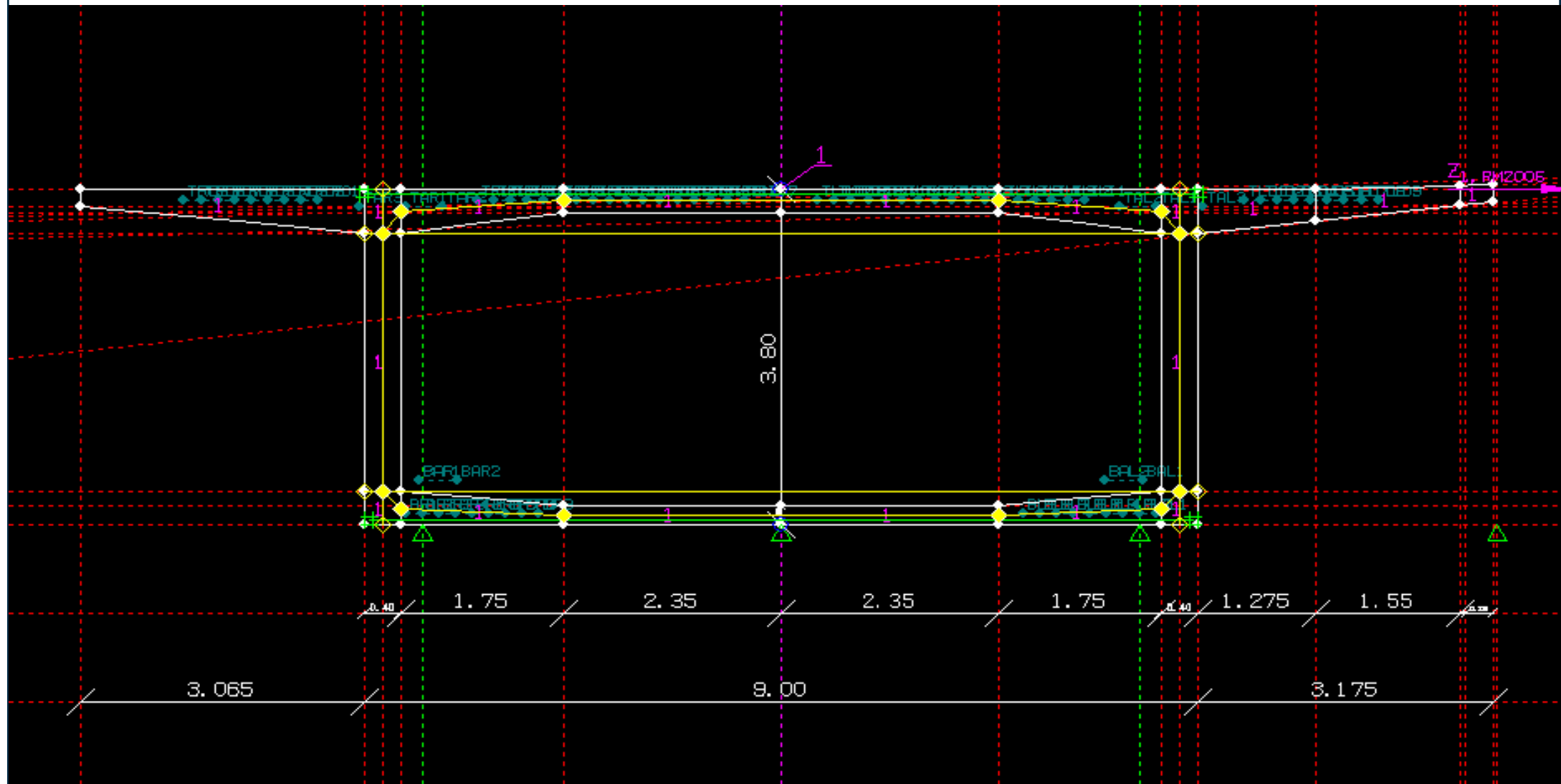
Tendone: 1101 1102 1103 1104 1105 1106 1107 1108 1109 1110 1201 1202 1203 1204 1
Schematic figure

14/04/2008
19:30

Cross Section Definition of Tendon Points



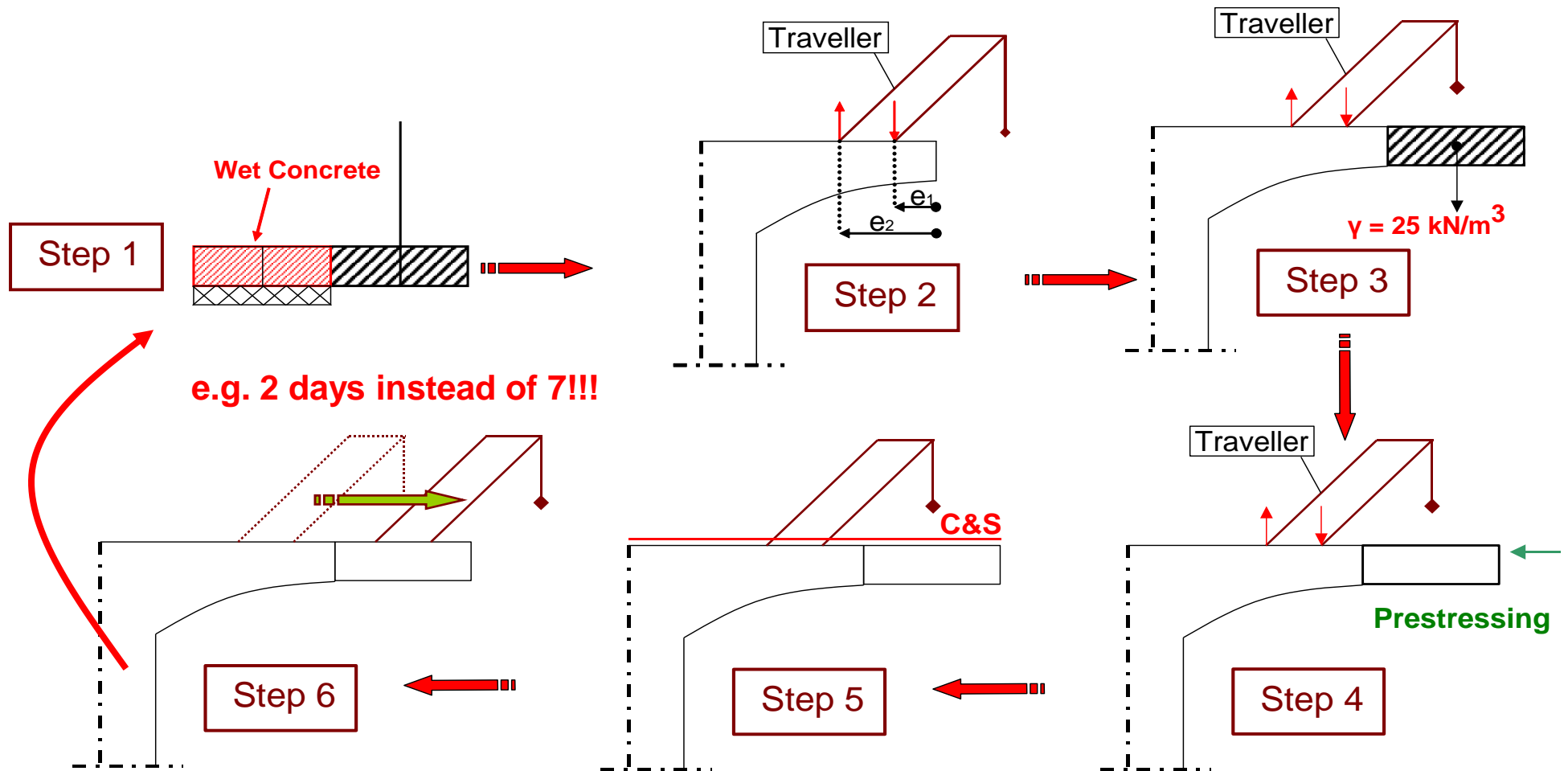
RM Cantilever TOOL



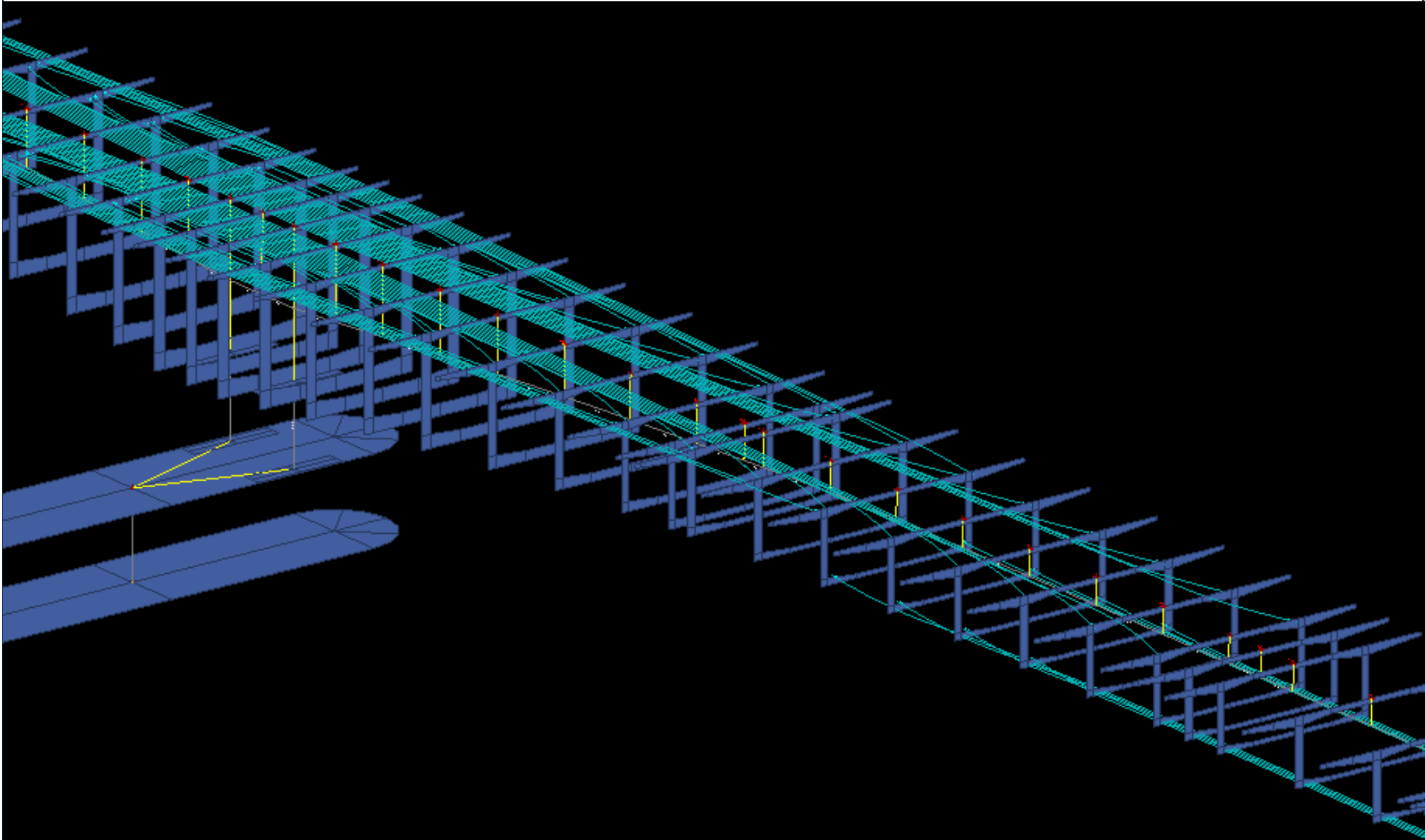
Cycle of construction stage



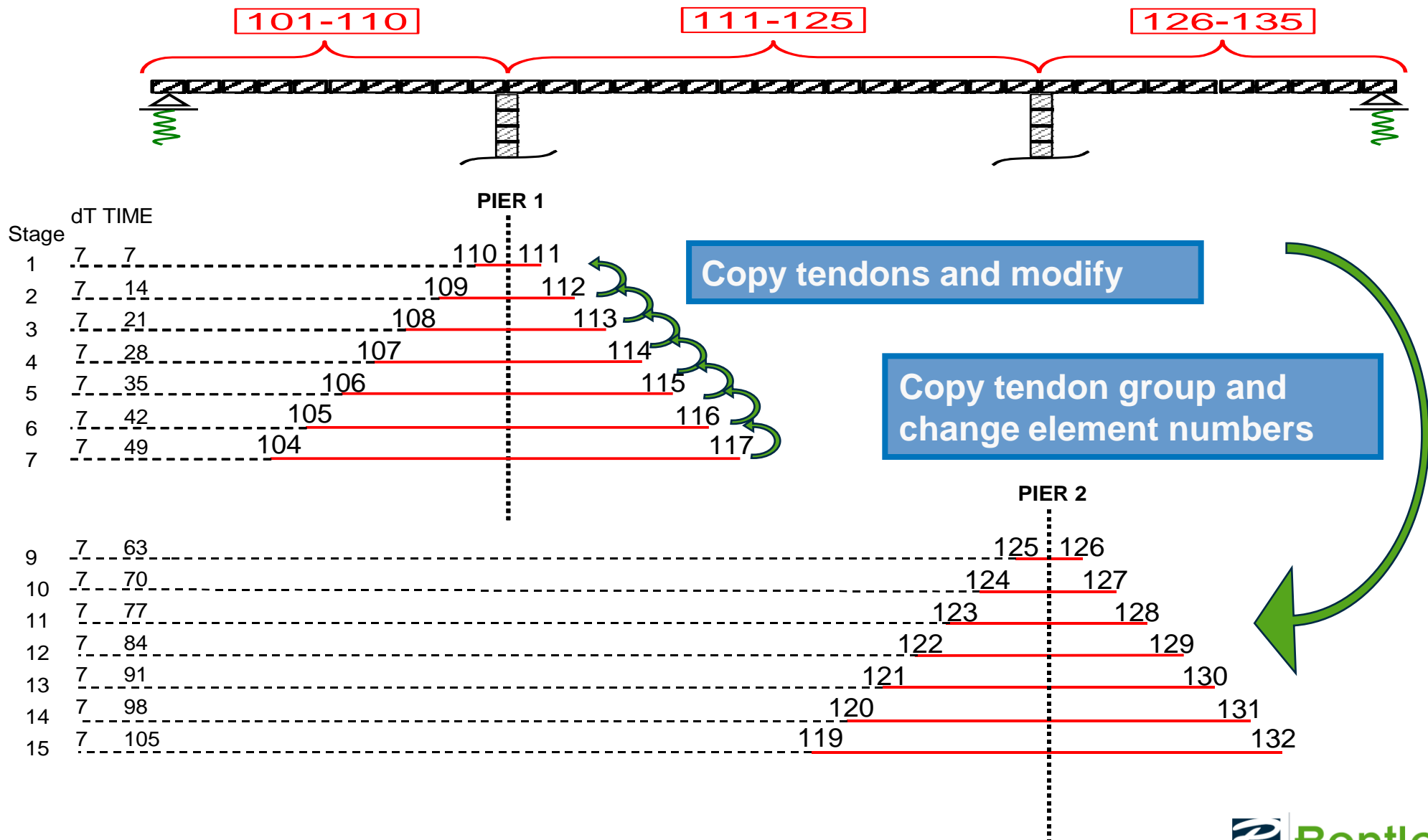
Balanced Cantilever Method basic concepts



Tendon Geometry



Tendon Management in RM-Tool



Creep and Shrinkage

- Creep:

- ε_c = plastic strain due to creep
- ε_e = elastic strain due to permanent load
- φ = creep factor
 - Global parameters such as quality of concrete, , environment (humidity, temperature,...)
 - Section properties
 - Age of concrete
 - Load application date when using CEB-I

$$\varepsilon_c = \varepsilon_e * \varphi$$

$$\varepsilon_e = \sum \varepsilon_{e,i} , \quad \varepsilon_c = \sum \varepsilon_{e,i} * \varphi$$

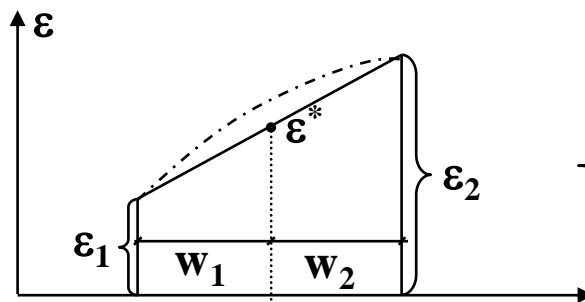
- Shrinkage:

- Total plastic strain consists of creep + shrinkage
 - Global parameters and section properties, similar to Creep
 - Age of concrete

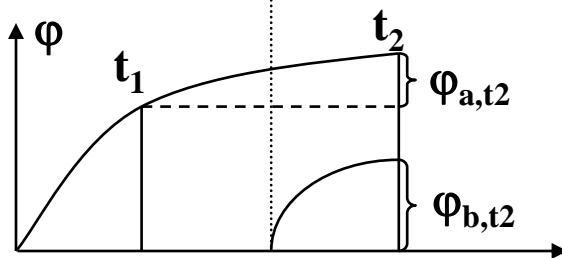
$$\varepsilon_p = \varepsilon_c + \varepsilon_s$$

Integral Equation

$$\varepsilon(t) = \frac{\sigma(t)}{E} \cdot [1 + \varphi(a, t)] + \int_a^t \frac{1}{E} \cdot \frac{\partial \sigma}{\partial \tau} \cdot \varphi(b, t) \cdot d\tau + \varepsilon_s(t)$$

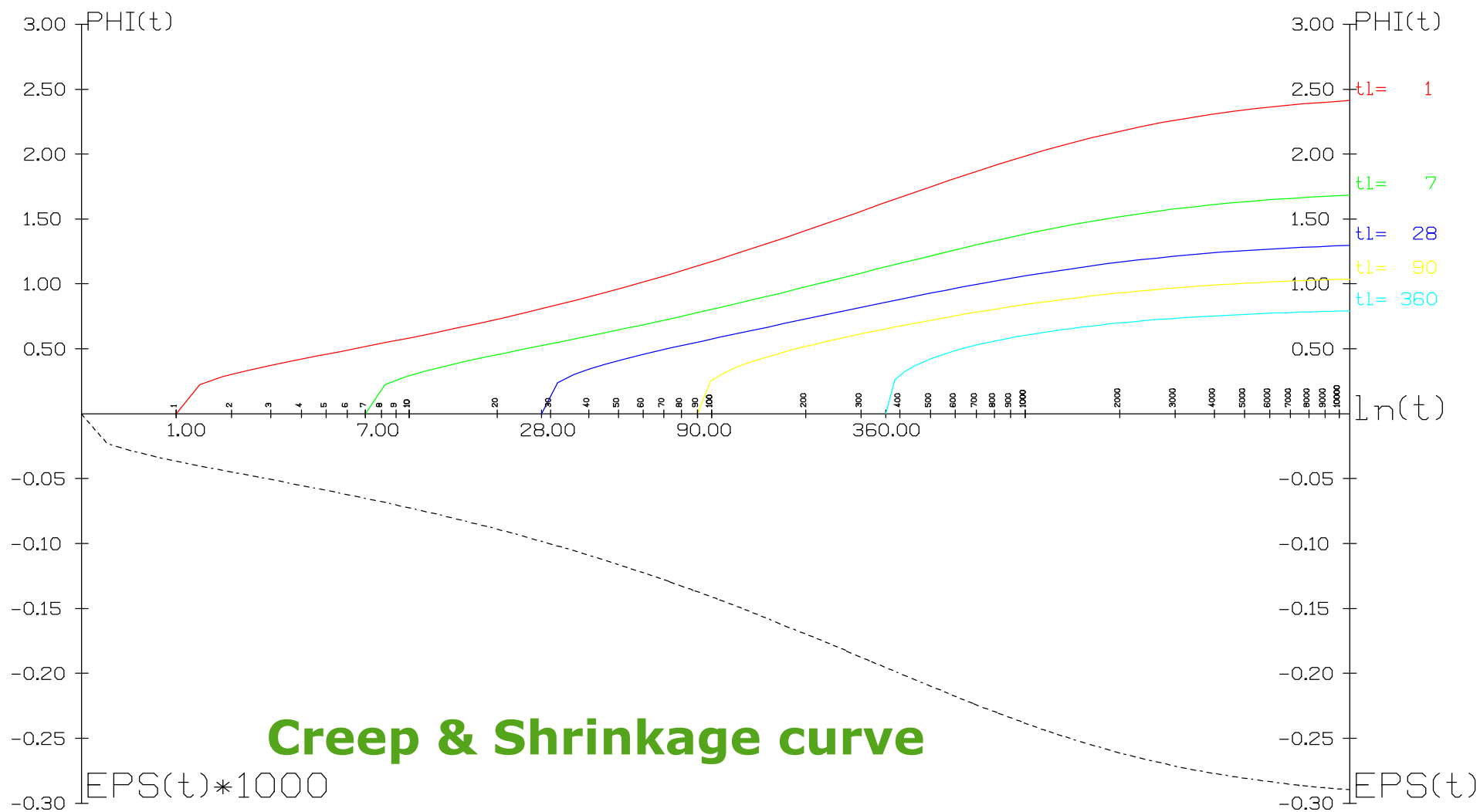


Averaging and linearisation according to “finite differences” theory



Creep curve ‘a’ for applied load (decomposed into increments)
Creep curve ‘b’ for stress increment occurring during time interval (construction stage) under consideration

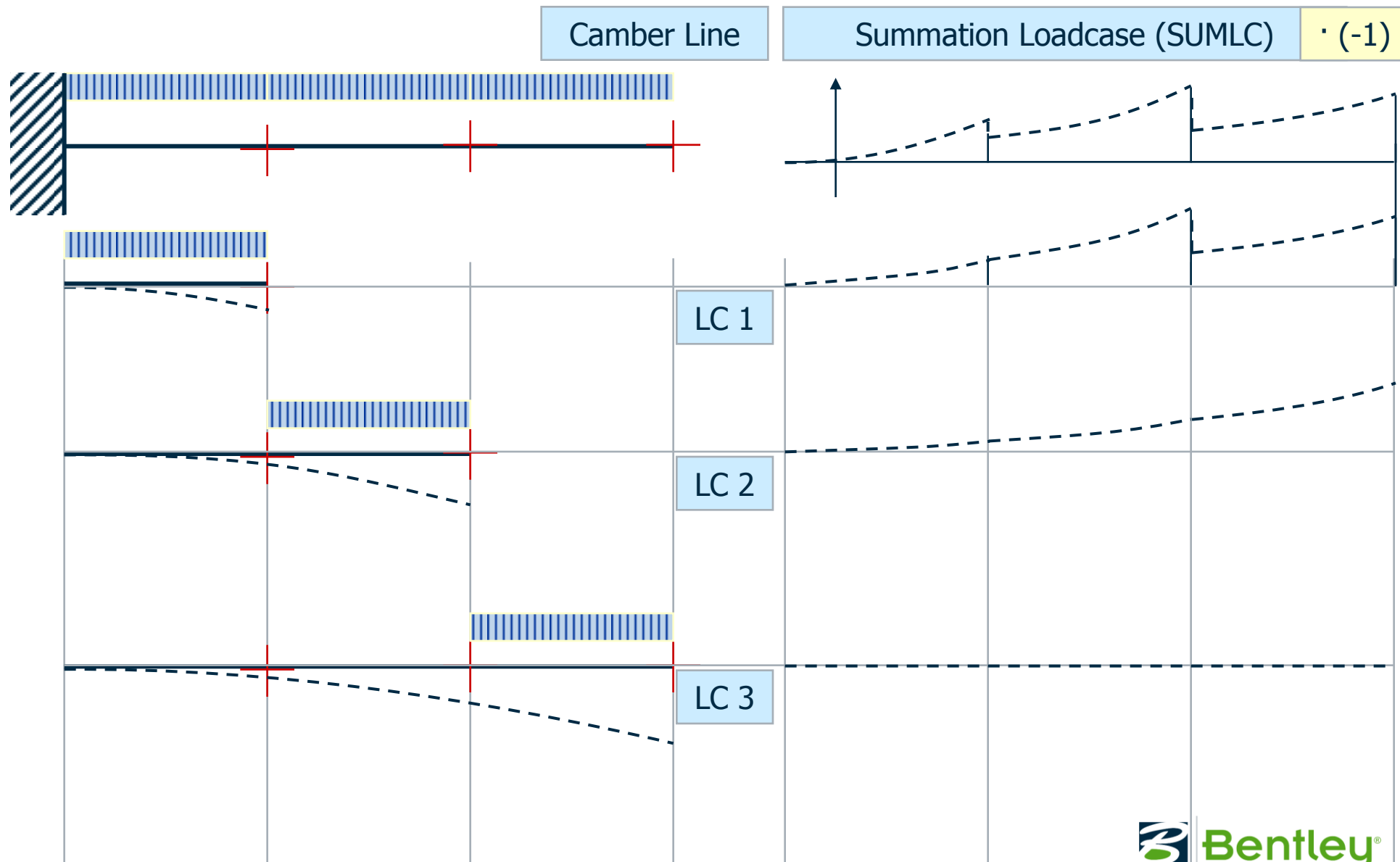
$$\varepsilon^* = \varepsilon_1 * W_2 + \varepsilon_2 * W_1$$



Creep & Shrinkage curve

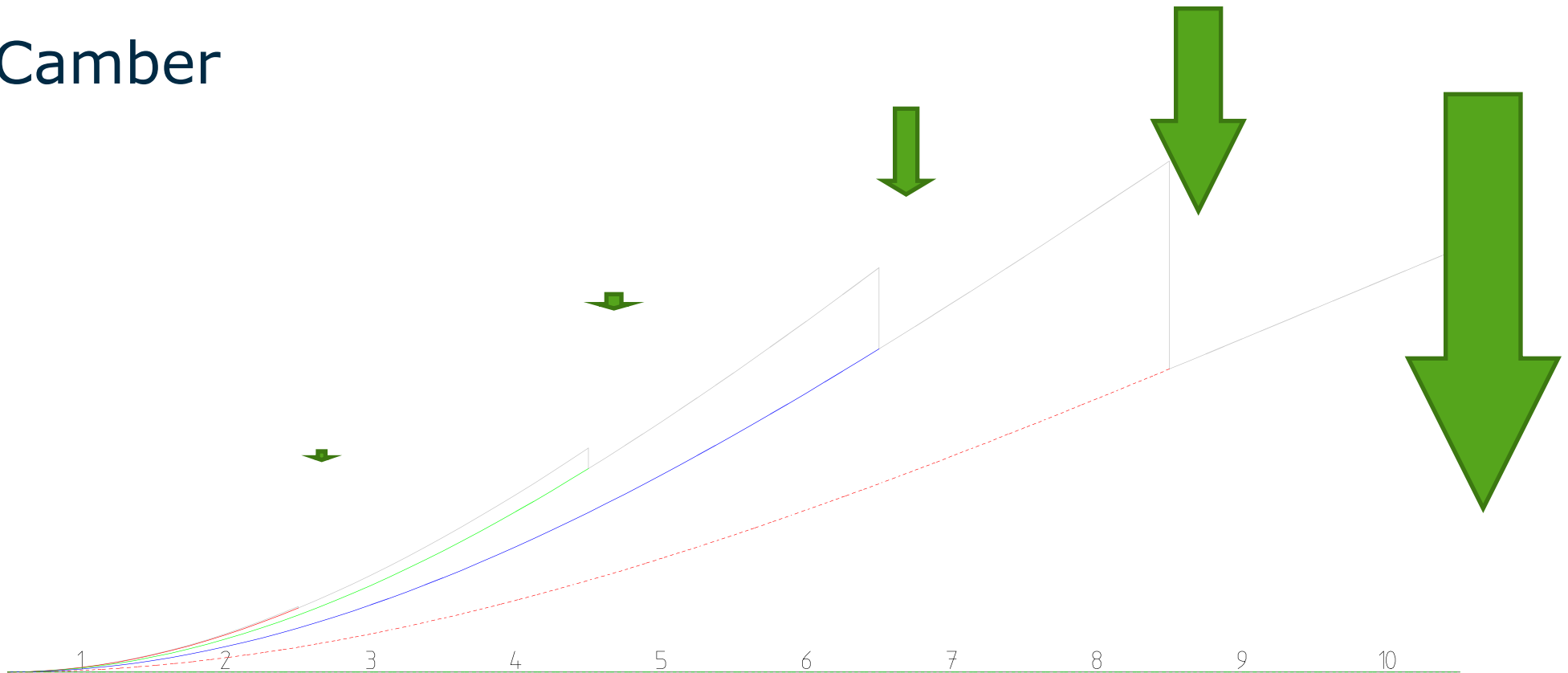
ASSHTO 1996

Cantilever Camber and Position

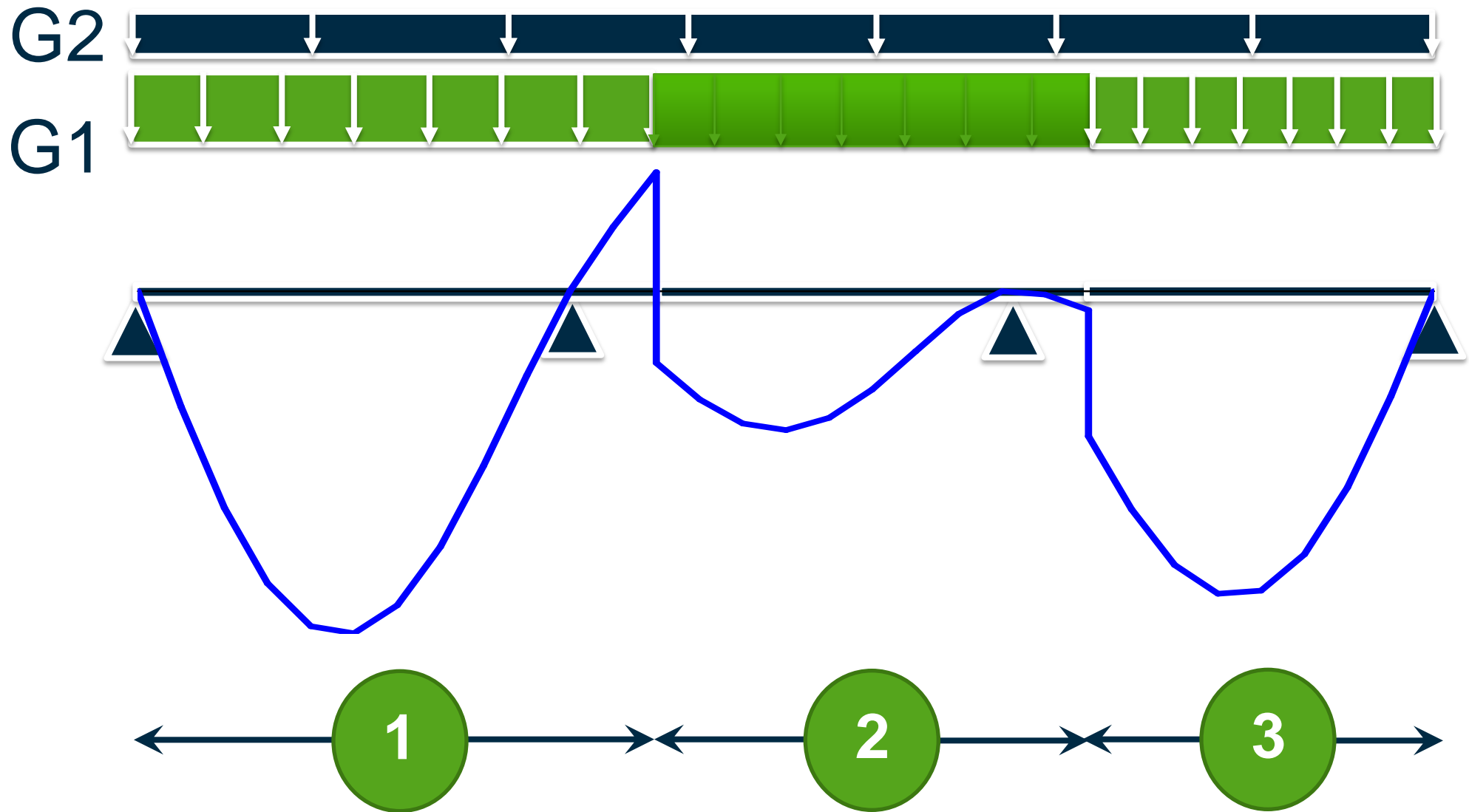


Cantilever with 5 steps

- Fabrication shape
- Camber



3-Span Bridge Camber Line



ADDCON: Optimization

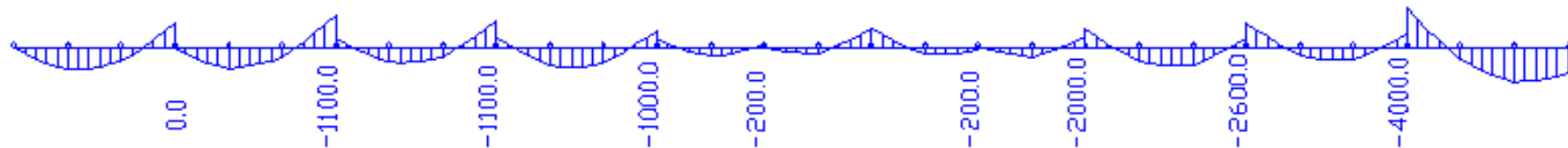
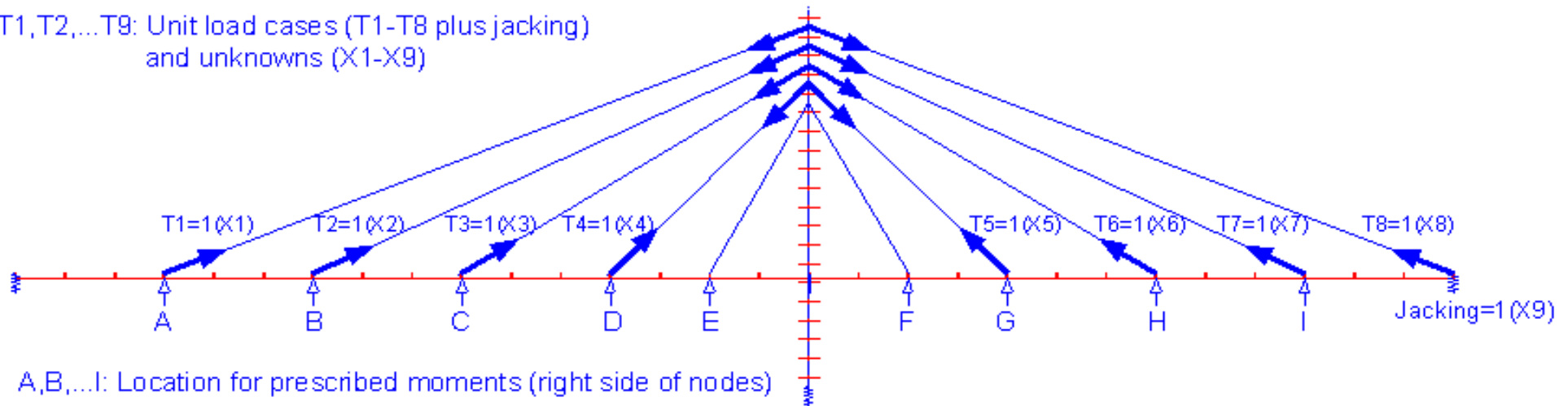
- Preparing a structural model
- Definition of
 - - Loads
 - - Construction schedule
 - - Corresponding ADDCON constraints
- Design criteria can be checked
- Optimisation can be started

Constraints

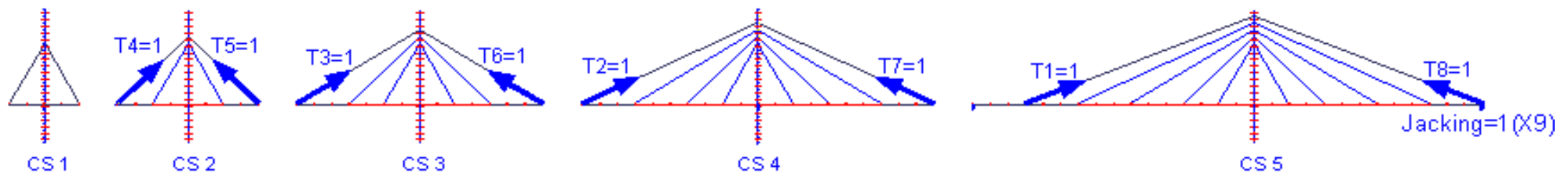
- Deformation of any point on the structure
- One of the internal forces at any point on the structure
- Stress at any cross-section at any point on the structure
- **Every constraint can be defined as a range of values**

Optimization of the Cable Forces

T1,T2,...T9: Unit load cases (T1-T8 plus jacking)
and unknowns (X1-X9)



CONSTRUCTION STAGES:

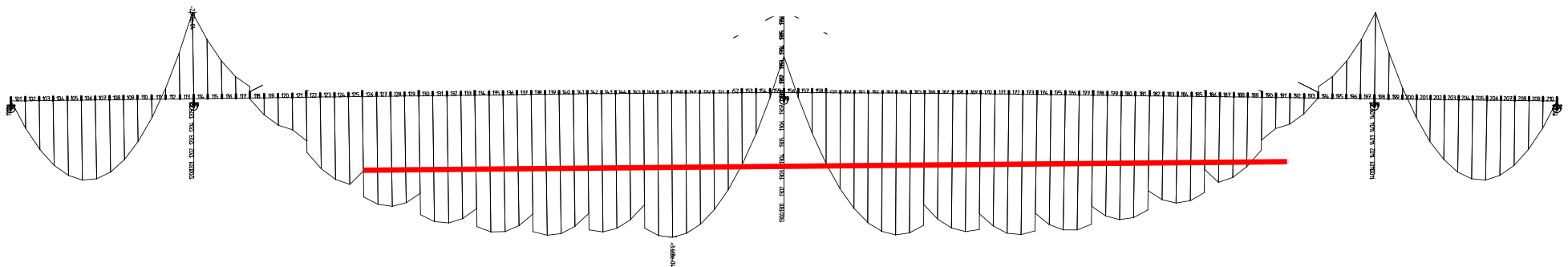


AddCon Method

- Provides a solution for finding the optimal tensioning strategy for the construction of cable-stayed bridges
- Include non-linear structural behaviour and time-dependent effects
- Computes the correct tensioning forces for the stay cables which lead exactly to a predetermined moment distribution and also to the intended geometry

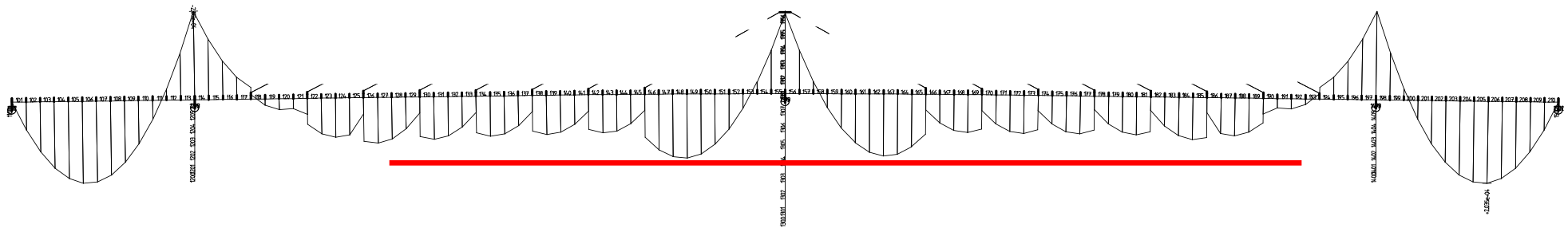
Choosing Constraints

- Defined boundary condition



After optimisation

- Defined boundary condition



RM Bridge Erection Control

- Expected position is not achieved during the construction of bridge:
 - Current position should be taken into account
- Compensation is made with pre-camber and fabrication shapes

**optimization of internal forces under
permanent loads**

X

choice of erections situations



Solution

- deformed structure is the start position:
 - full account of location in space is taken into account
 - implemented procedure is repeated interactively until convergence criteria
- fabrication shape is applied as loading:
 - control and optimization of forces and displacements
- kink correction for structural assembly:
 - control or simulation of construction in face-to-face connections
- kink correction for structural assembly:
 - control or simulation of construction in face-to-face connections

novel solution: based on displacement constraints

Fabrication Shape

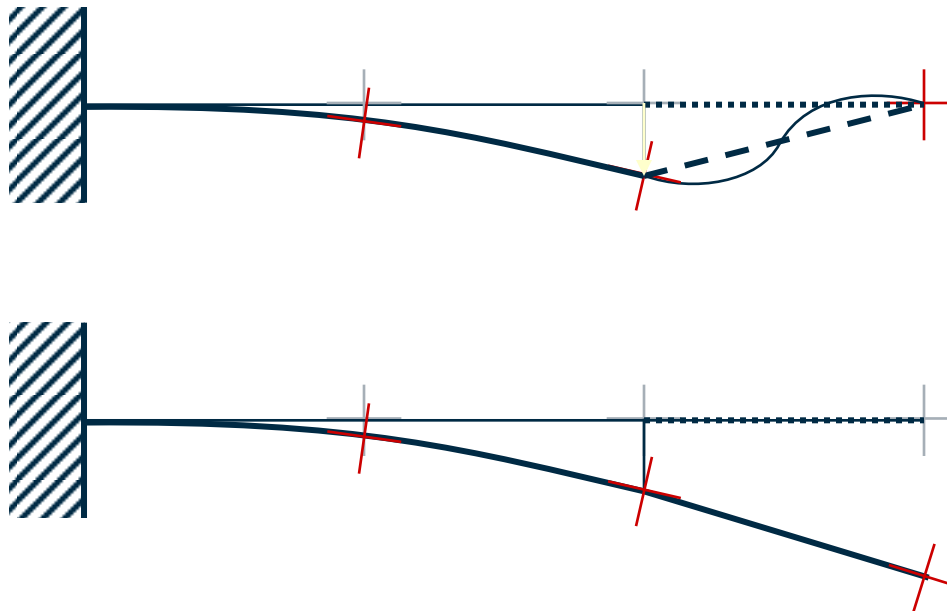
- Definition of the bridge segment stress free geometry WITHOUT rigid body part
- There is only one fabrication shape per bridge segment



Kink Correction

- How does it work?

$$\delta_{corr} = \delta^{Node} - \delta^{Element}$$



Iteration

RM CAST Tool

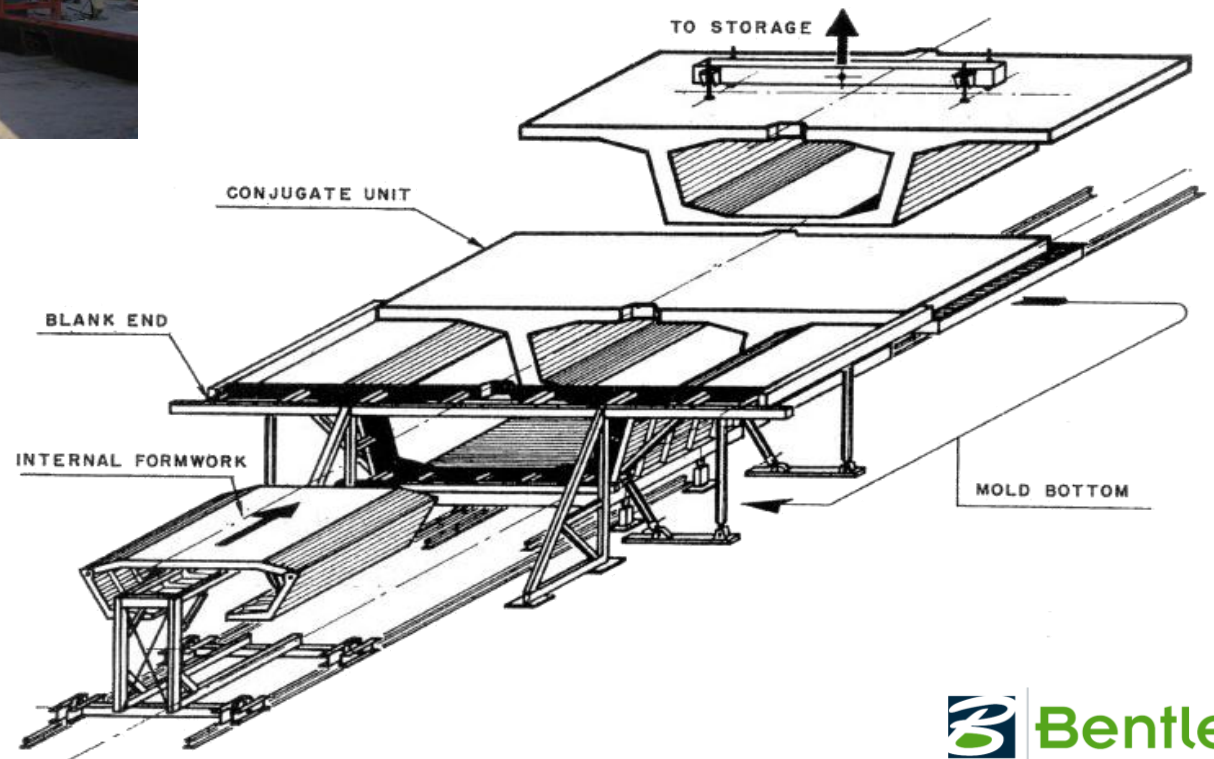
In Factory: control points

Short Line Match Casting



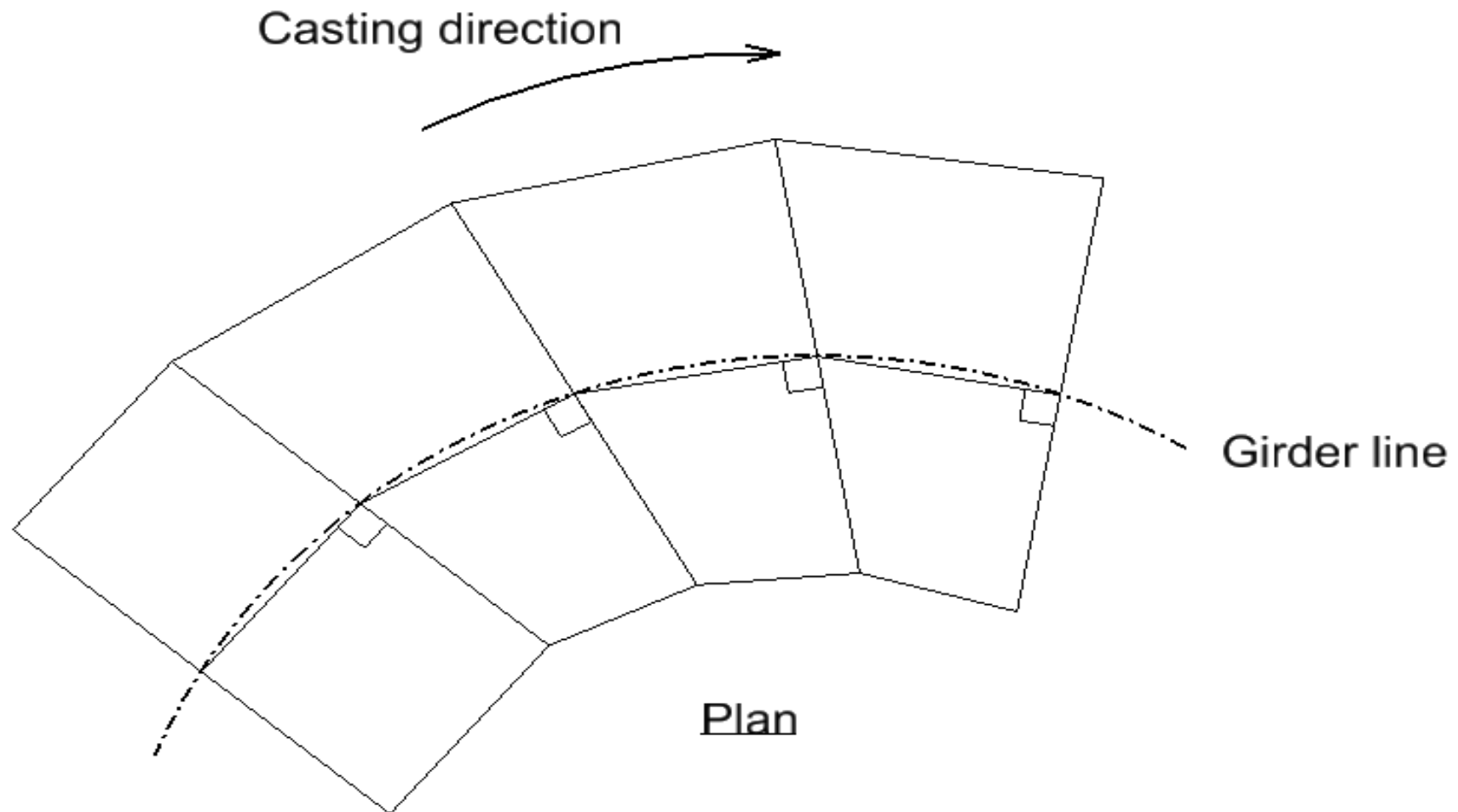
Idea of Short Line Match Casting

- Perfect match at segment joints



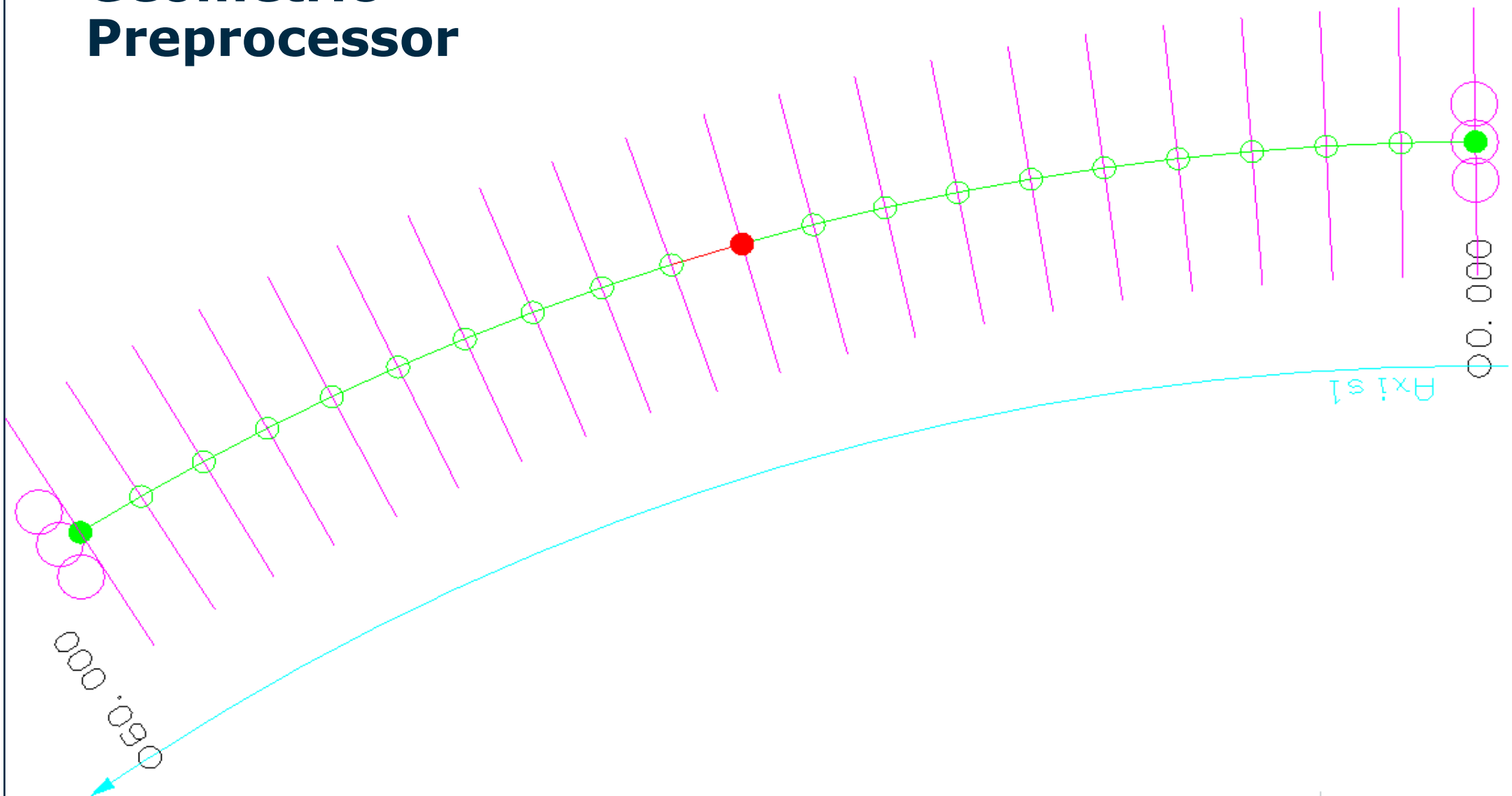
Short Line Match Casting

Casting sequence



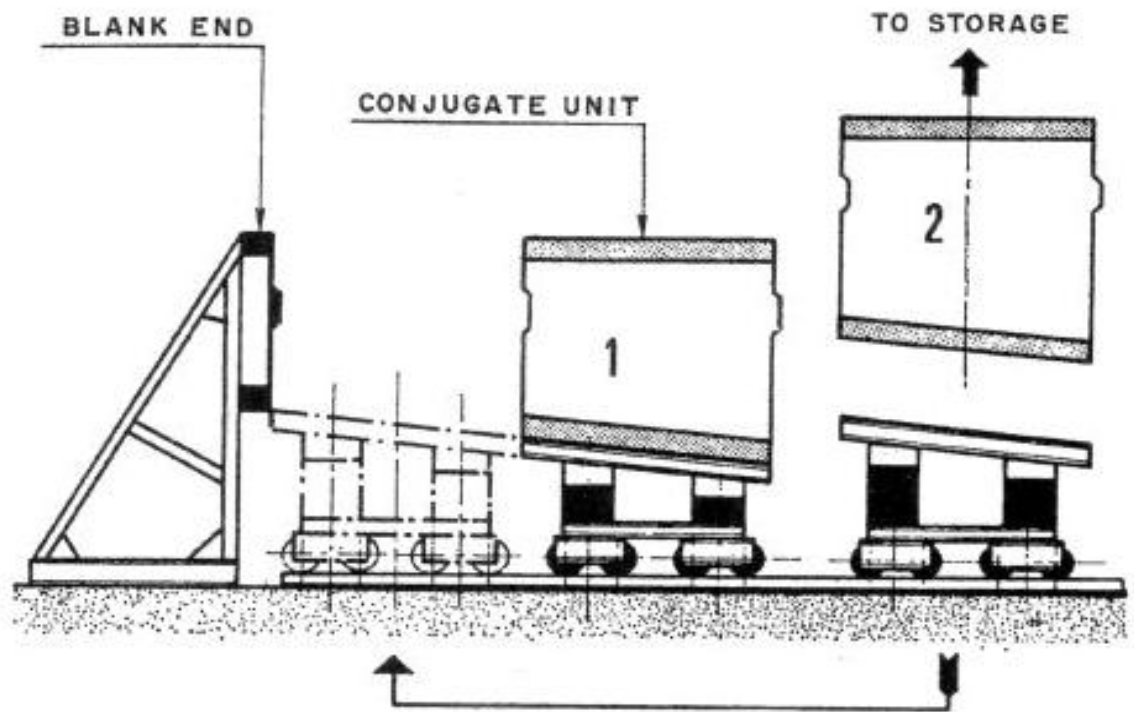
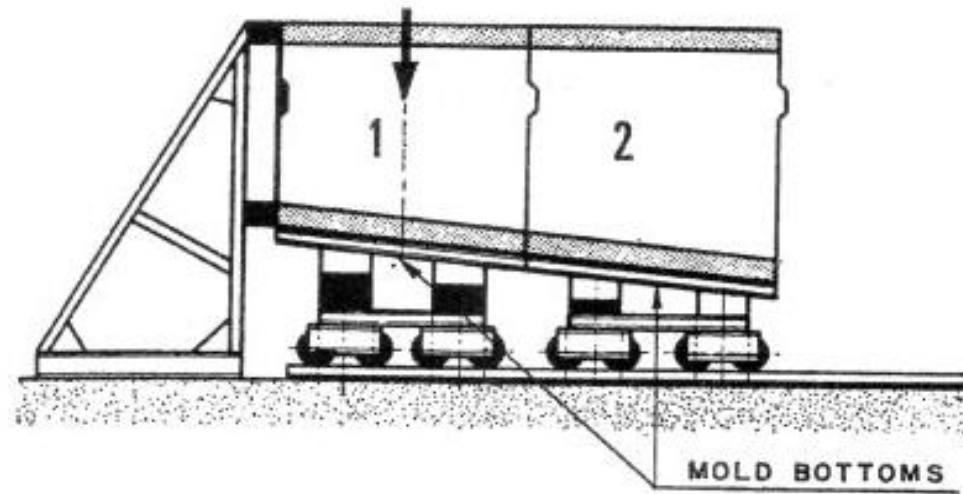
Bentley Bridge RM - GP

Geometric Preprocessor

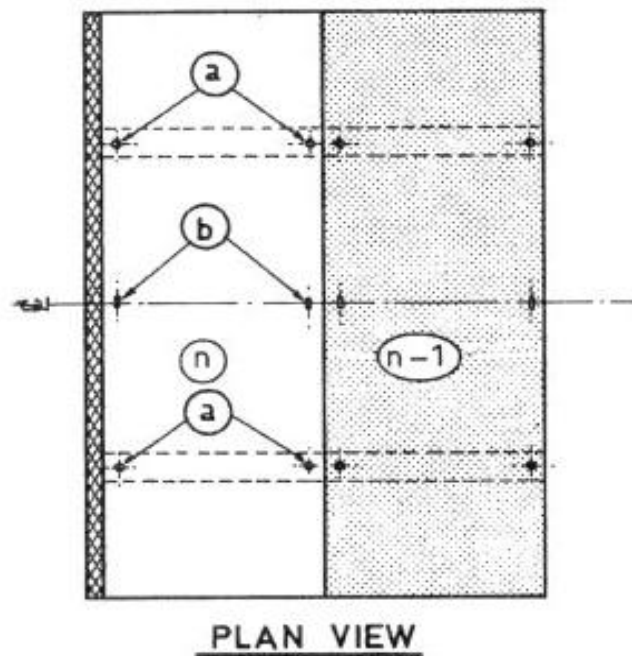
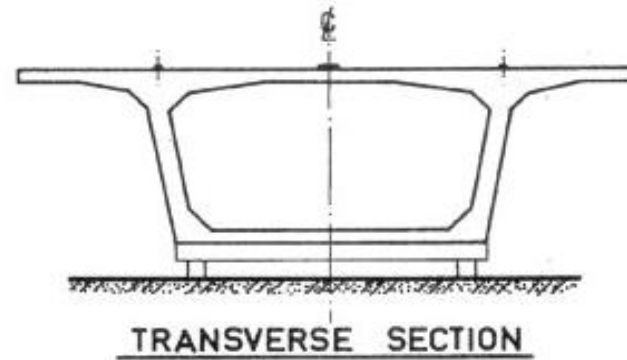
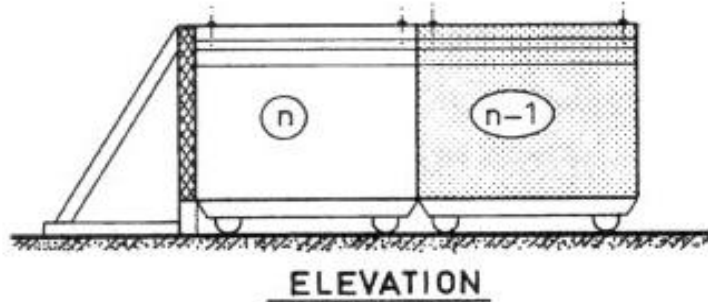


Short Line Match Casting

Casting sequence



Short Line Match Casting

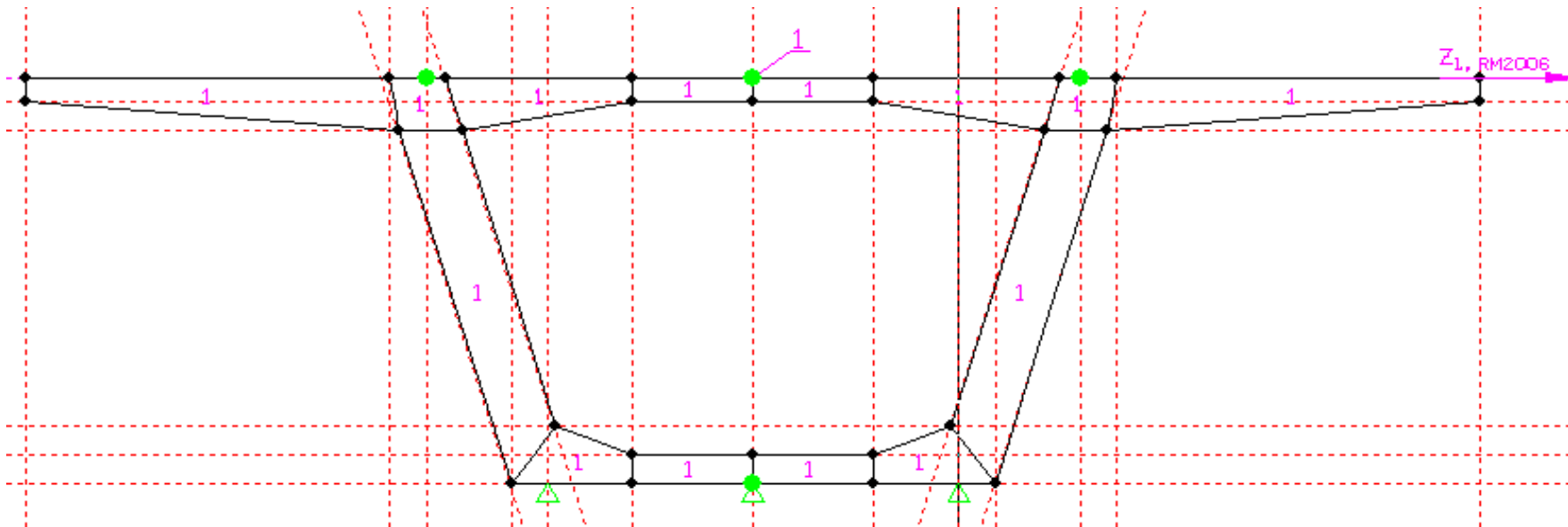


STRAIGHT BRIDGE

Preparation in GP

Definitions for

- Rivet positions
- Segmentation
- Casting sequence



- Four geometry points

- Name1(co)

- Name2(el), Name3(el)

- lentgh

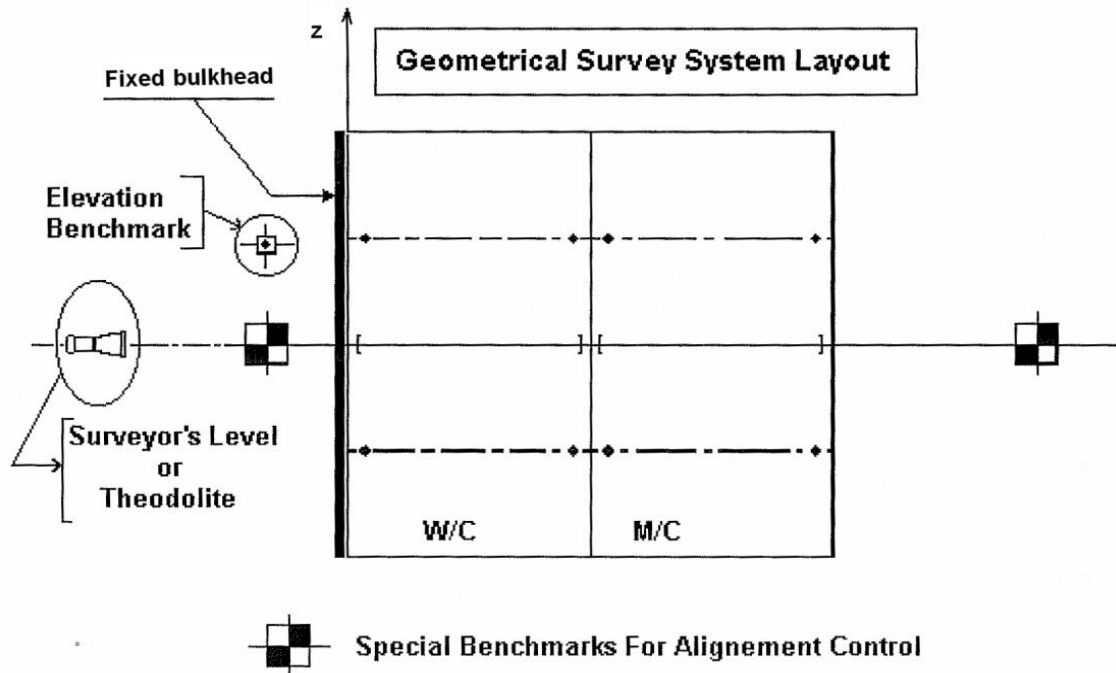
- Name4(b)

center, offset
elevation,

bottom

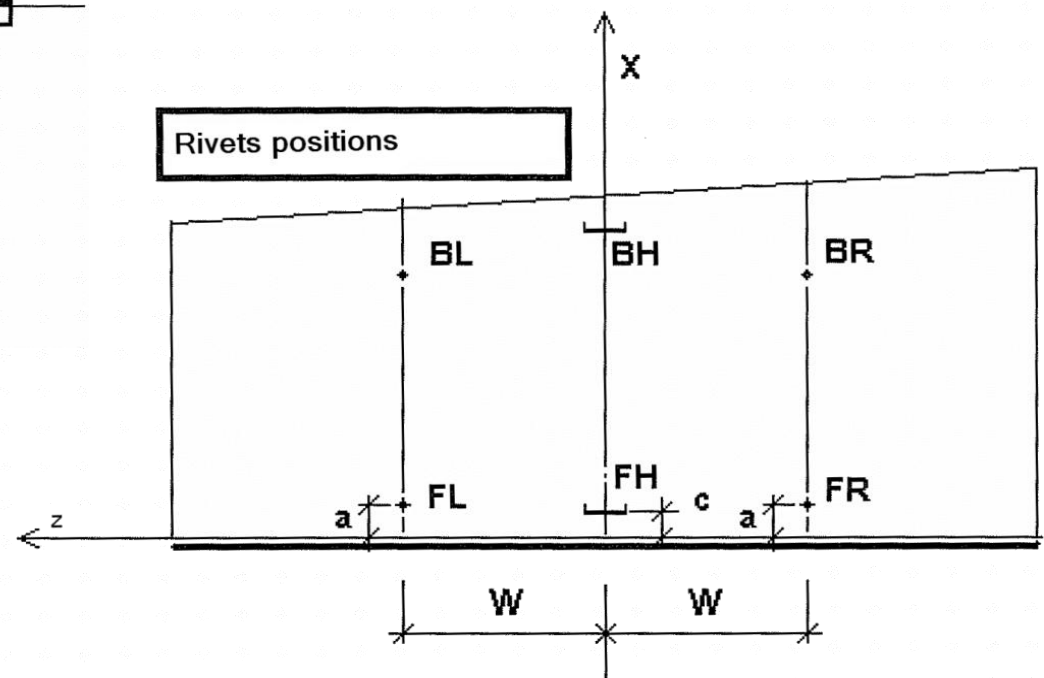
Short Line Match Casting

Measuring the segments

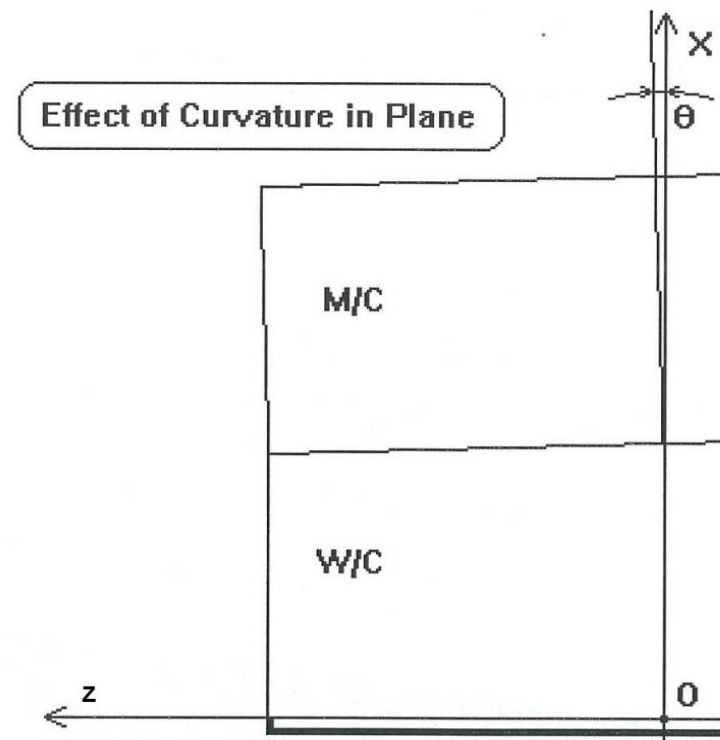
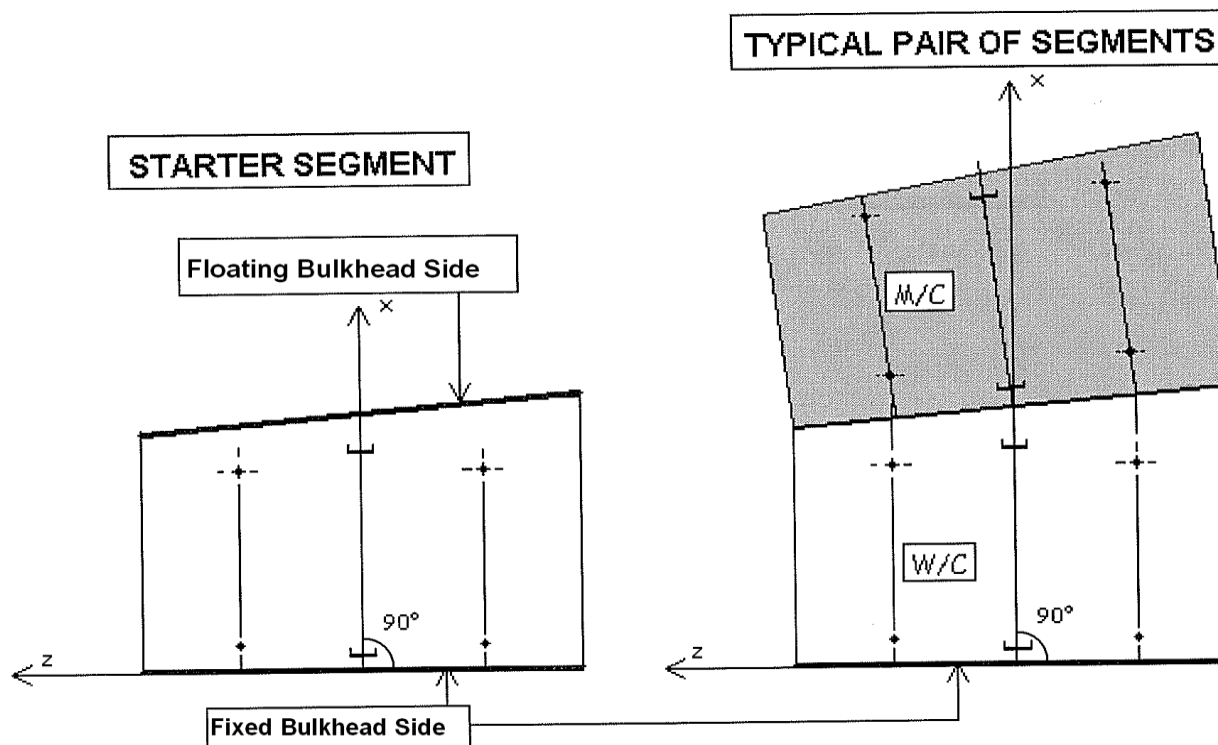


- Distance from joint (a, c)
- Distance from centerline (W)

- Aluminium bolts for elevation and length
- Horizontal stirrups

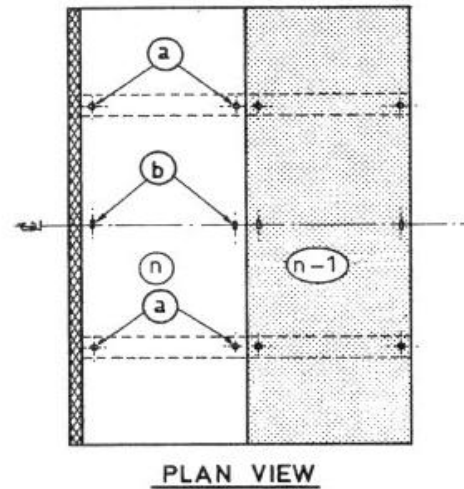
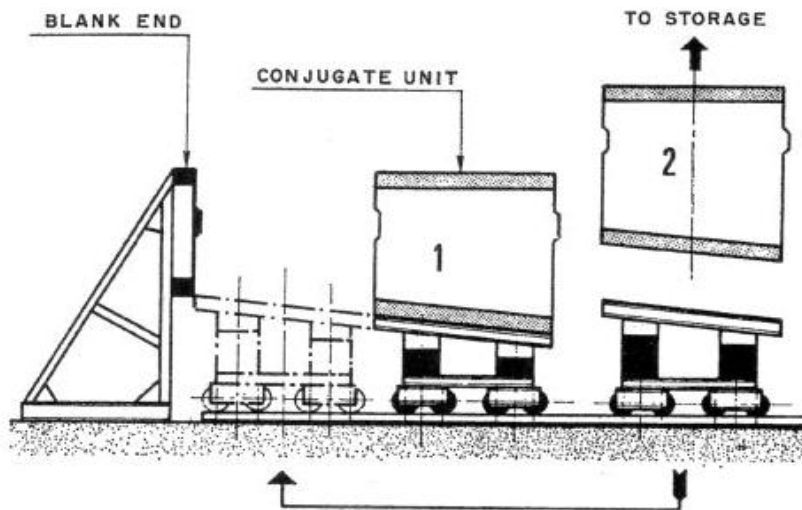
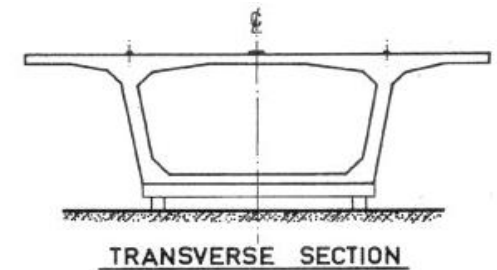
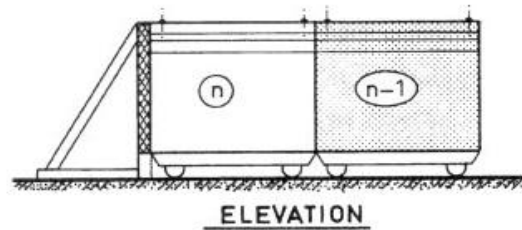
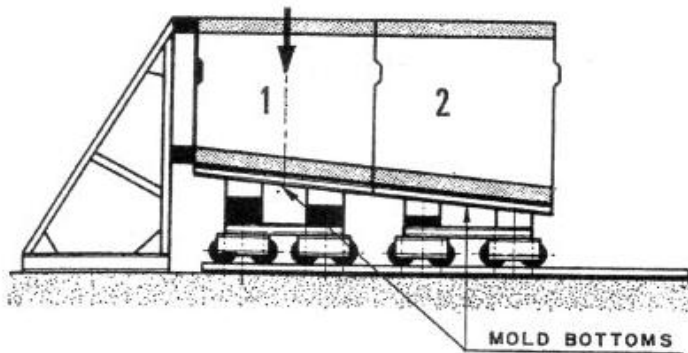


Short Line Match Casting



Short Line Match Casting

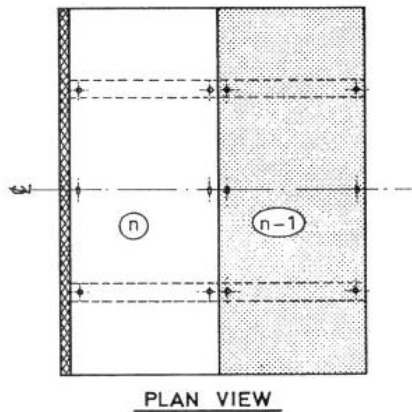
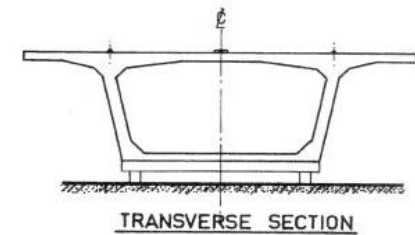
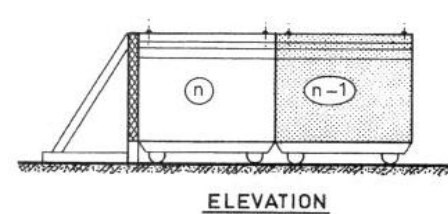
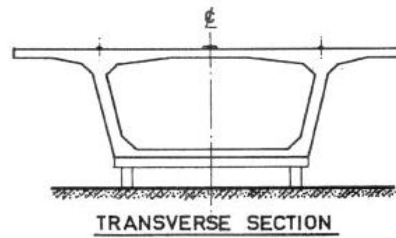
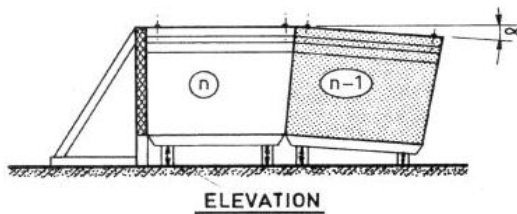
Casting sequence



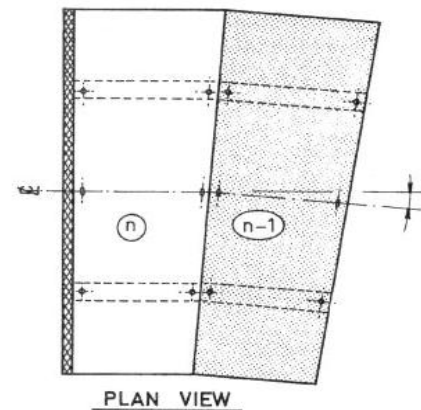
STRAIGHT BRIDGE

Short Line Match Casting

Casting sequence

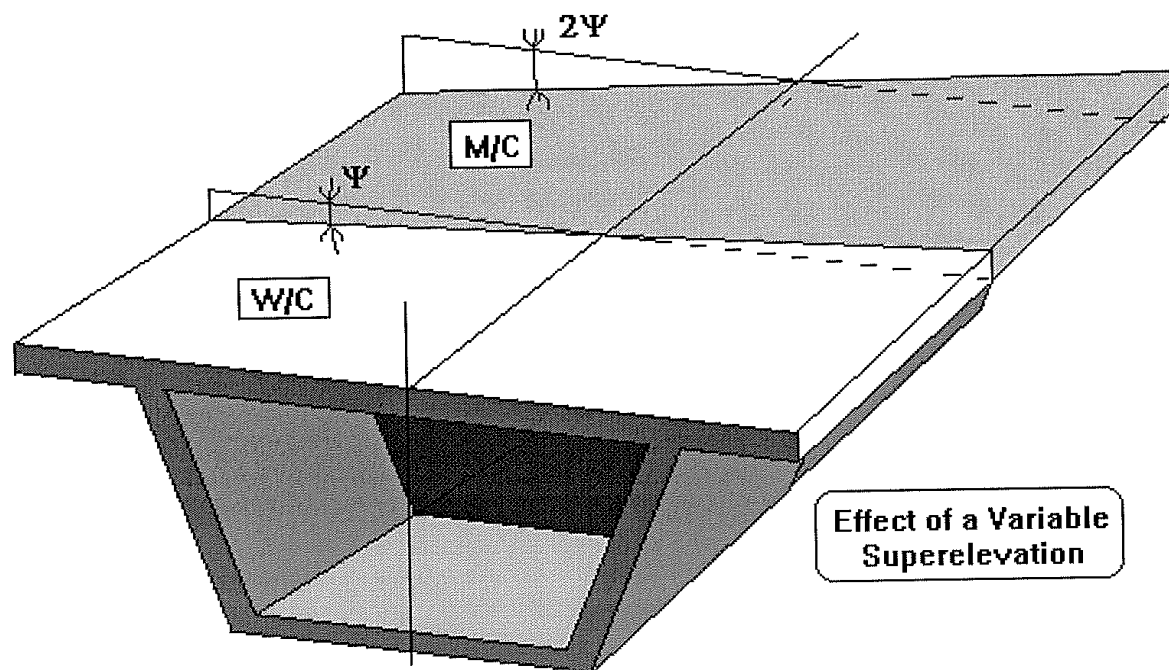
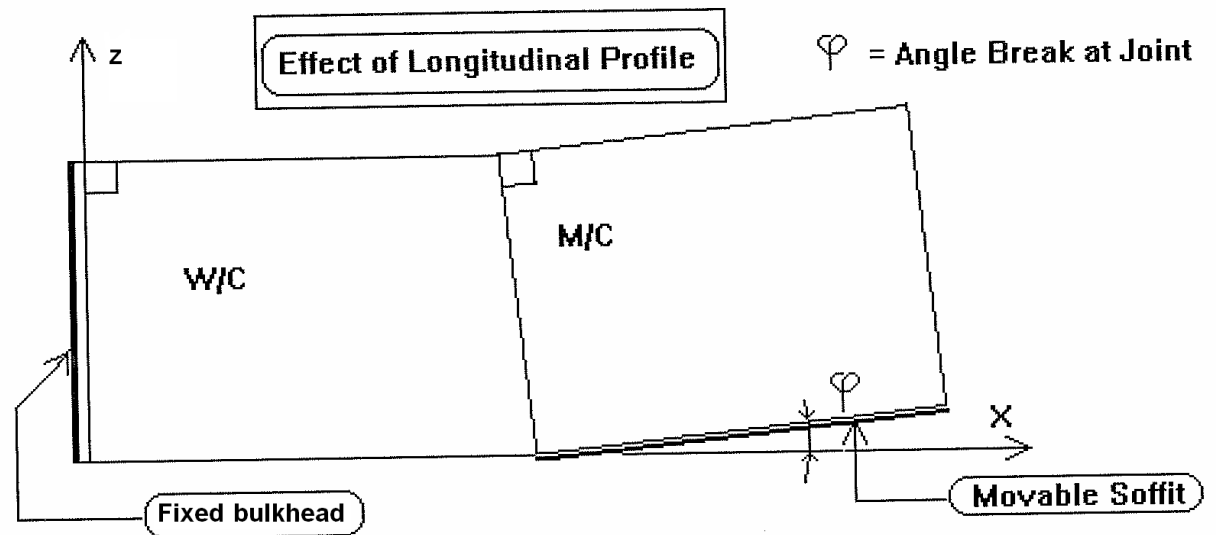


BRIDGE WITH
VERTICAL CURVE

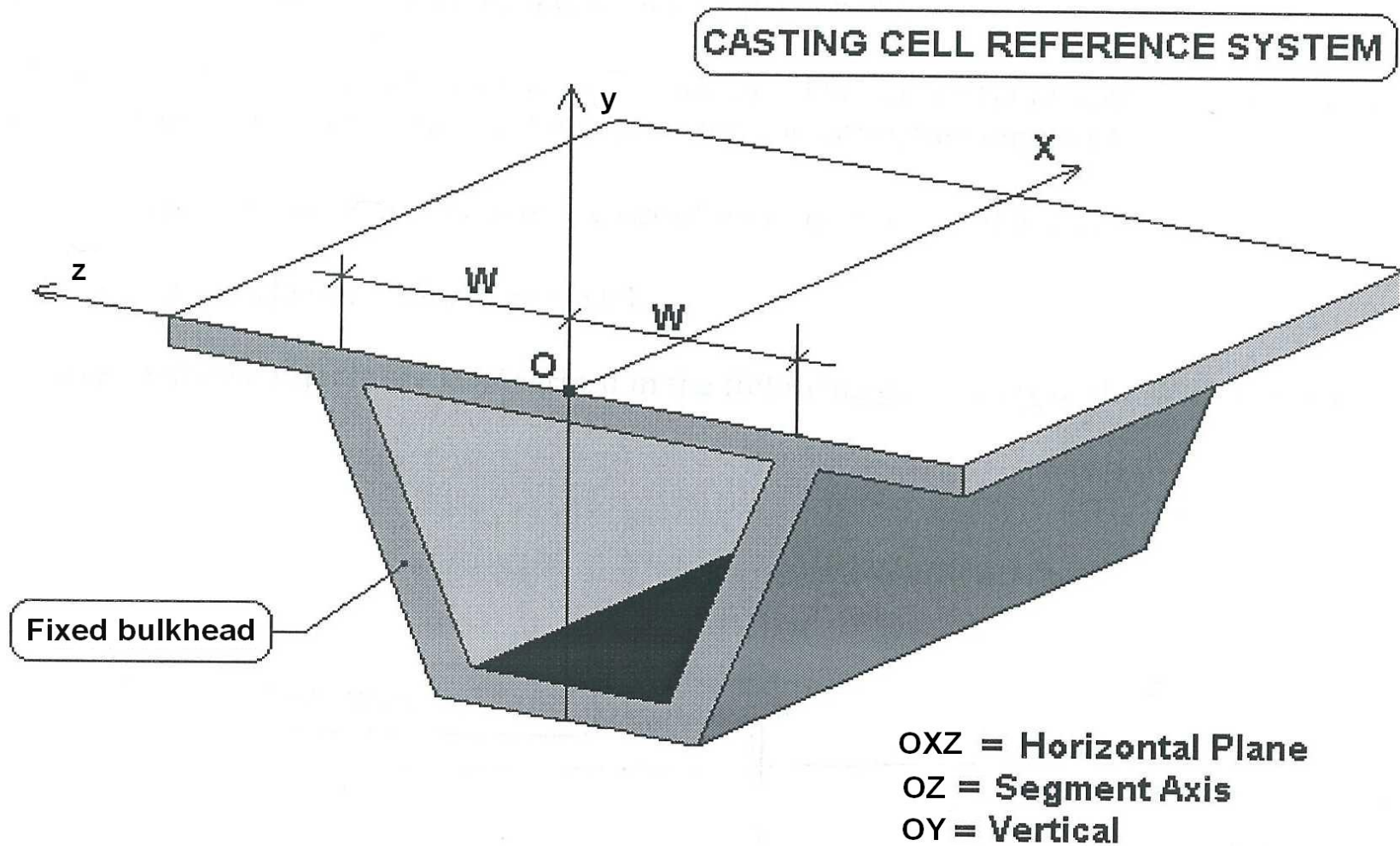


BRIDGE WITH
HORIZONTAL CURVE

Effects



Geometry coordinates

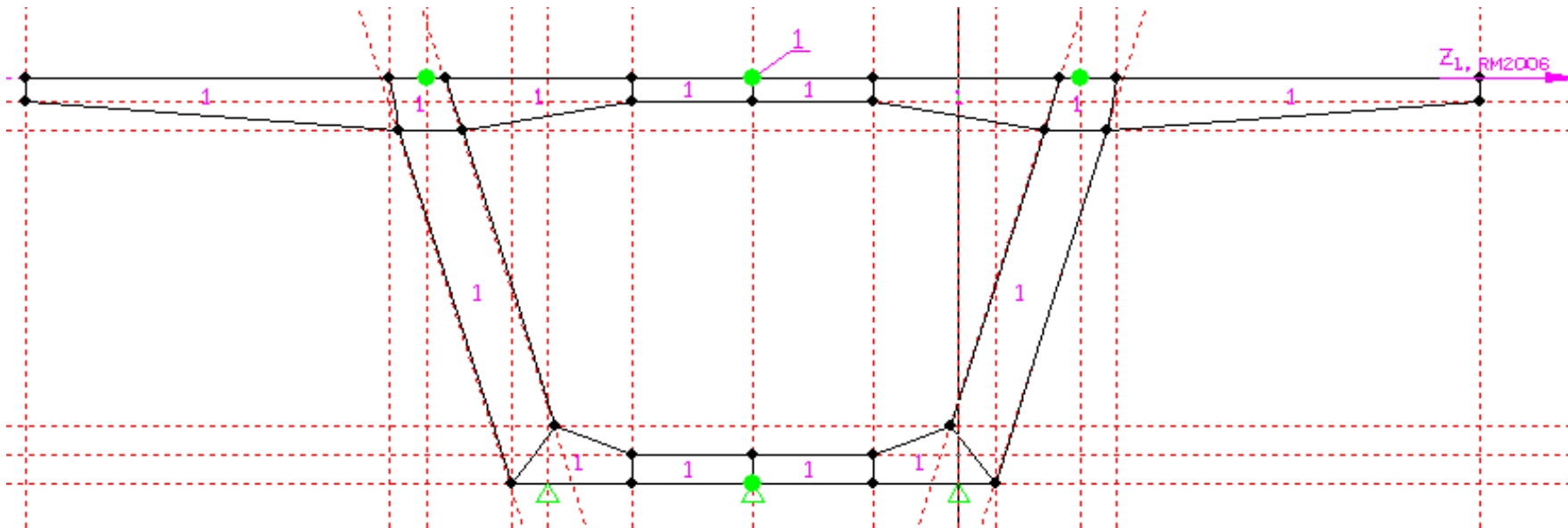




Preparation in GP

Definitions for

- Rivet positions
- Segmentation
- Casting sequence



- Four geometry points

- Name1(co)

- Name2(el), Name3(el)

- Name4(h)

center, offset
elevation,

bottom

Preparation in GP

Definitions for

- Rivet positions
- Segmentation
- Casting sequence

The screenshot displays the GP software interface for bridge preparation. The main window shows a table titled 'Elements in Segment "Bridge"'. The table has columns: No., Station, Length, Cross Section, ok, Segmentation, Dir., Input Length, and Computed Length. The data is as follows:

No.	Station	Length	Cross Section	ok	Segmentation	Dir.	Input Length	Computed Length
1	0.0000	5.0000	Deck	+	Start	s+	5.0000	5.0000
2	5.0000	5.0000	Deck	+	Intermediate	s+	5.0000	5.0000
3	10.0000	5.0000	Deck	+	Intermediate	s+	5.0000	5.0000
4	15.0000	5.0000	Deck	+	Intermediate	s+	5.0000	5.0000
5	20.0000	5.0000	Deck	+	Intermediate	s+	5.0000	5.0000
6	25.0000	5.0000	Deck	+	Closure	s+	5.0000	5.0000
7	30.0000	5.0000	Deck	+	Intermediate	s-	5.0000	5.0000
8	35.0000	5.0000	Deck	+	Intermediate	s-	5.0000	5.0000
9	40.0000	5.0000	Deck	+	Intermediate	s-	5.0000	5.0000
10	45.0000	5.0000	Deck	+	Intermediate	s-	5.0000	5.0000
11	50.0000	5.0000	Deck	+	Start	s-	5.0000	5.0000

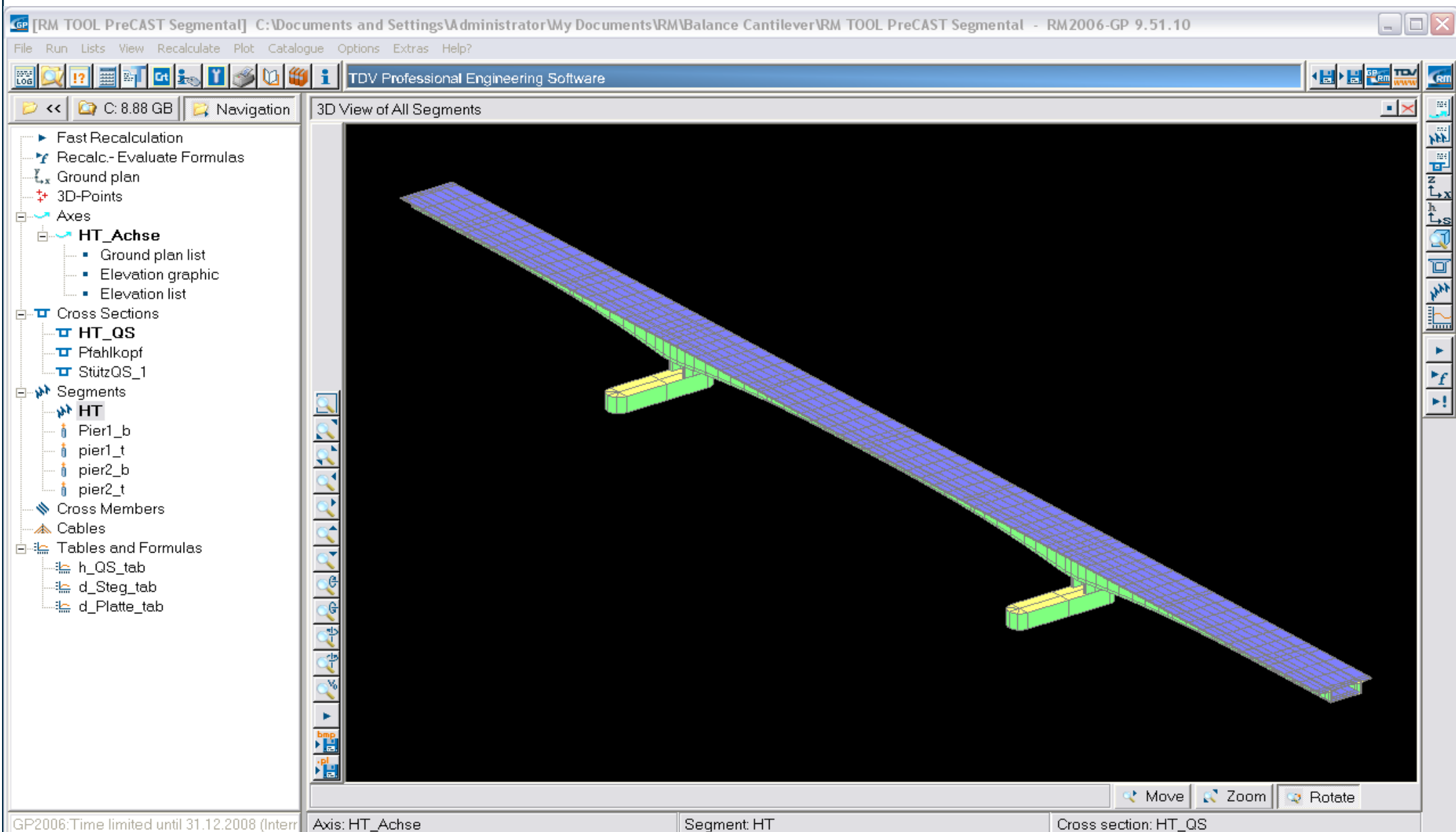
The 'Edit Segment Elements' dialog box is open, showing options for modifying cross section, station, segmentation length, and segmentation type. The 'Modify segmentation length' and 'Modify segmentation type' sections are highlighted with a red circle. The 'Segmentation' and 'Dir.' columns in the table are also highlighted with a red circle.

The 'Composite Parts' table is also visible, showing the following data:

Composite Parts	Beam	Material	Group	Node Numbers
	1101	OeN_Austria:C_35/45	ULEFT	1101 1102

- Casting direction
- Segment type
- Segment length

RM2006 - GP





Preparation in RM

- Preparation following the principles of camber calculation
- Final export to RMCast with module “DoCast”

Status	Name	Date	Time (Day)	Duration (Day)	Make camber	Description
Ok	1	07/01/2008	0.0	0.0	Beg+End	
Ok	2	07/01/2008	0.0	0.0	Beg+End	
Ok	3	07/01/2008	0.0	0.0	Beg+End	
Ok	4	07/01/2008	0.0	0.0	Beg+End	
Ok	5	07/01/2008	0.0	0.0	Beg+End	
Ok	6	07/01/2008	0.0	0.0	Beg+End	
Ok	Camber	07/01/2008	0.0	0.0		

Status	Command	Inp1	Inp2	Inp3	Out1	Out2	Delta-T	Time
Ok	DoCamber	*					0.0	0.0
Ok	DoCamber	*	Camber		camber-pos.xls		0.0	0.0
Ok	DoCamber	end		Camber:Camber	*		0.0	0.0
Ok	DoCast	Cast	Camber		rmcast-ex.cast	*	0.0	0.0

Elements for casting are define in RM-Set:

- First element must be starter
- Side where next element joins must be given

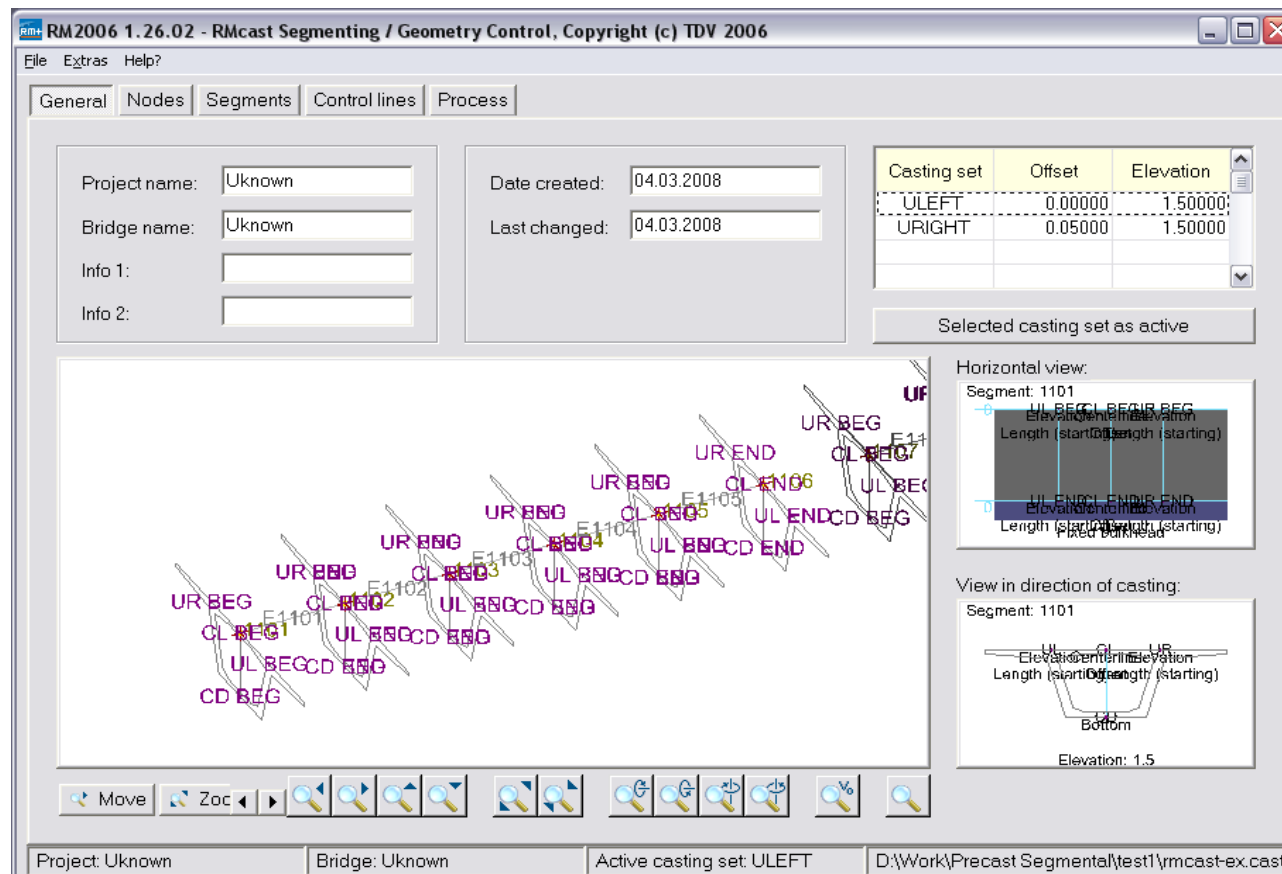
Object	Col1	Col2	Col3	Col4	Col5
TYPE	RESULT				
ELEM	1101	1105	1	E	
ELEM	1111	1107	-1	B	
NODE	1101	1112	1		

High 5 - Dallas



RM Cast

RM Cast is a tool to help casting segments in the casting yard. Small inaccuracies which may occur during casting can be corrected and the setup of other segments is changed.



RM Cast

Typical casting steps:

- Setup match cast segment
- Setup wet cast rivets/stirrups
- Pour segment
- Survey rivets/stirrups
- Correct casting curve

Process

Surveying starting segment 1102 and match-cast segment 1101

Date: 06.03.2008

Begin

Elevation 1.50241 Offset: 0.00000 Elevation 1.50241

UL CL UR

Elevation 1.50000 Offset: 0.00000 Elevation 1.50000

Elevation 1.50000 Offset: 0.00000 Elevation 1.50000

Length: 4.99955

UL CL UR

End

End Begin

End

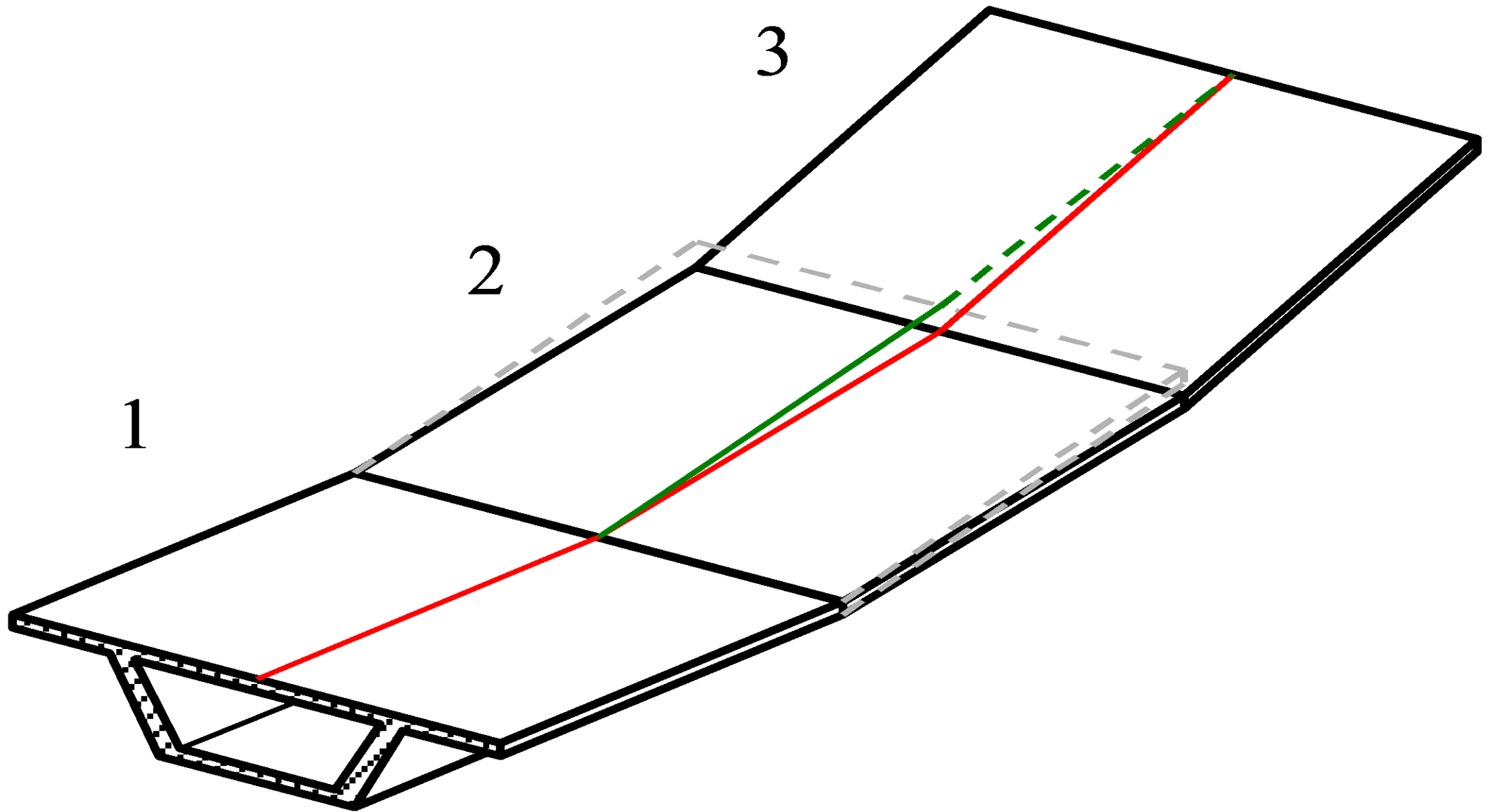
Fixed bulkhead

Setup bulkhead Setup rivets Survey Preview Finish

☒ Include elevation ☒ Perfect cast ☒ Simplified frame

Cancel

RM Cast



RM Cast

Report generation

Project: Unknown

Bridge: Unknown

Date: 06.03.2008

Wet-cast segment: 1104

Match-cast segment: 1103

Match-cast

UL Begin	CL Begin	UR Begin
Offset: 2.70000	Offset: 0.00000	Offset: -2.70000
Elevation: 1.50039	Elevation: 1.50039	Elevation: 1.50039

UL End	CL End	UR End
Offset: 2.70000	Offset: 0.00000	Offset: -2.70000
Elevation: 1.50000	Elevation: 1.50000	Elevation: 1.50000
Length: 4.99998	Length: 4.99998	Length: 4.99998

Wet-cast

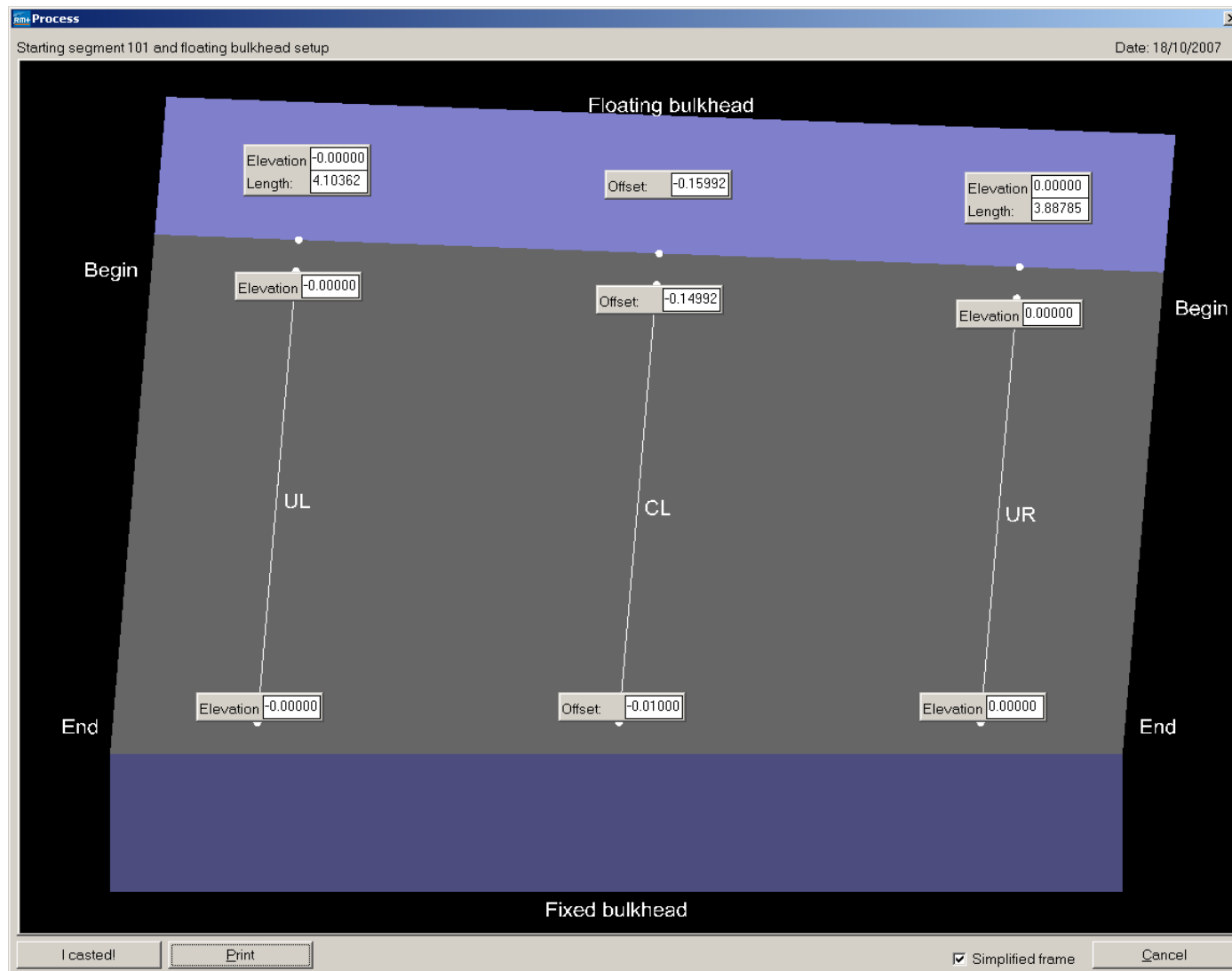
UL Begin	CL Begin	UR Begin
Offset: 2.70000	Offset: 0.00000	Offset: -2.70000
Elevation: 1.50000	Elevation: 1.50000	Elevation: 1.50000
Length: 4.99998	Length: 4.99998	Length: 4.99998

UL End	CL End	UR End
Offset: 2.70000	Offset: 0.00000	Offset: -2.70000
Elevation: 1.50000	Elevation: 1.50000	Elevation: 1.50000
Length: 0.00000	Length: 0.00000	Length: 0.00000

Fixed bulkhead

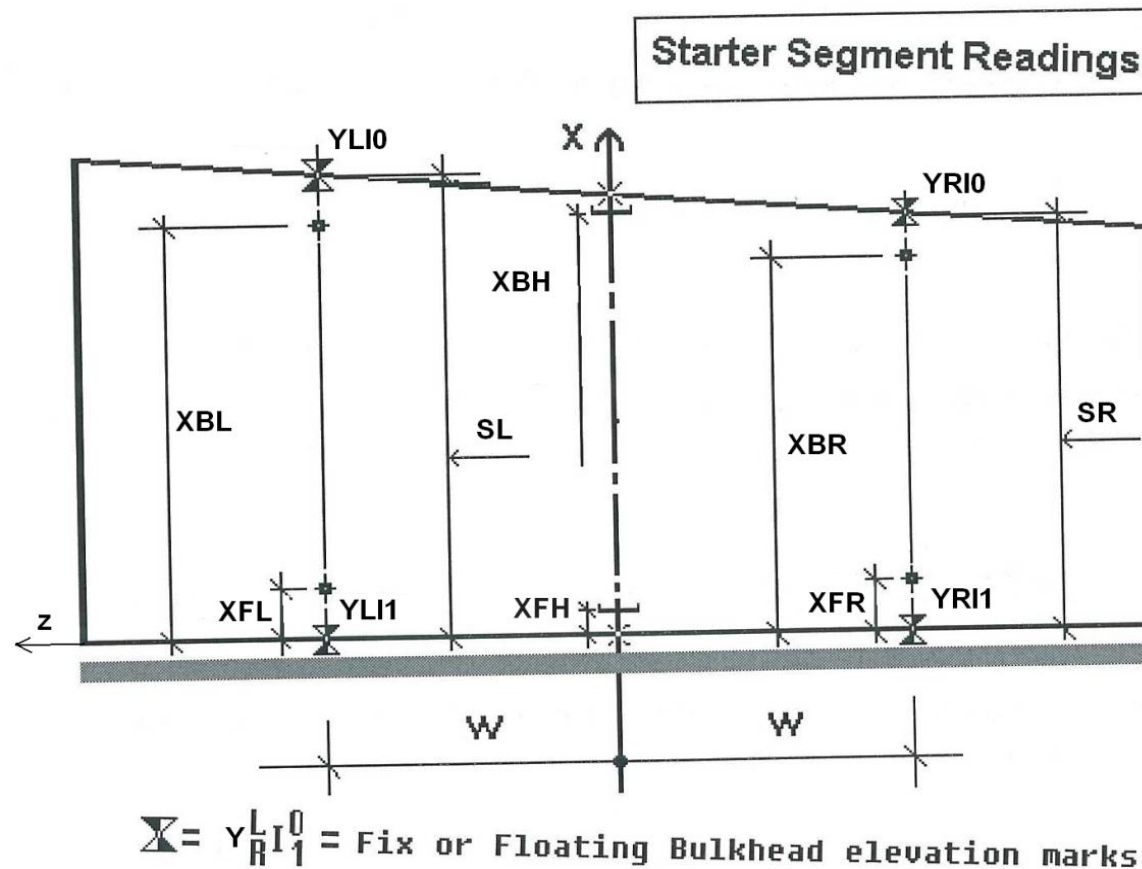
UL	CL	UR
Offset: 2.70000	Offset: 0.00000	Offset: -2.70000
Elevation: 0.00000	Elevation: 0.00000	Elevation: 0.00000

Prepare starting segment

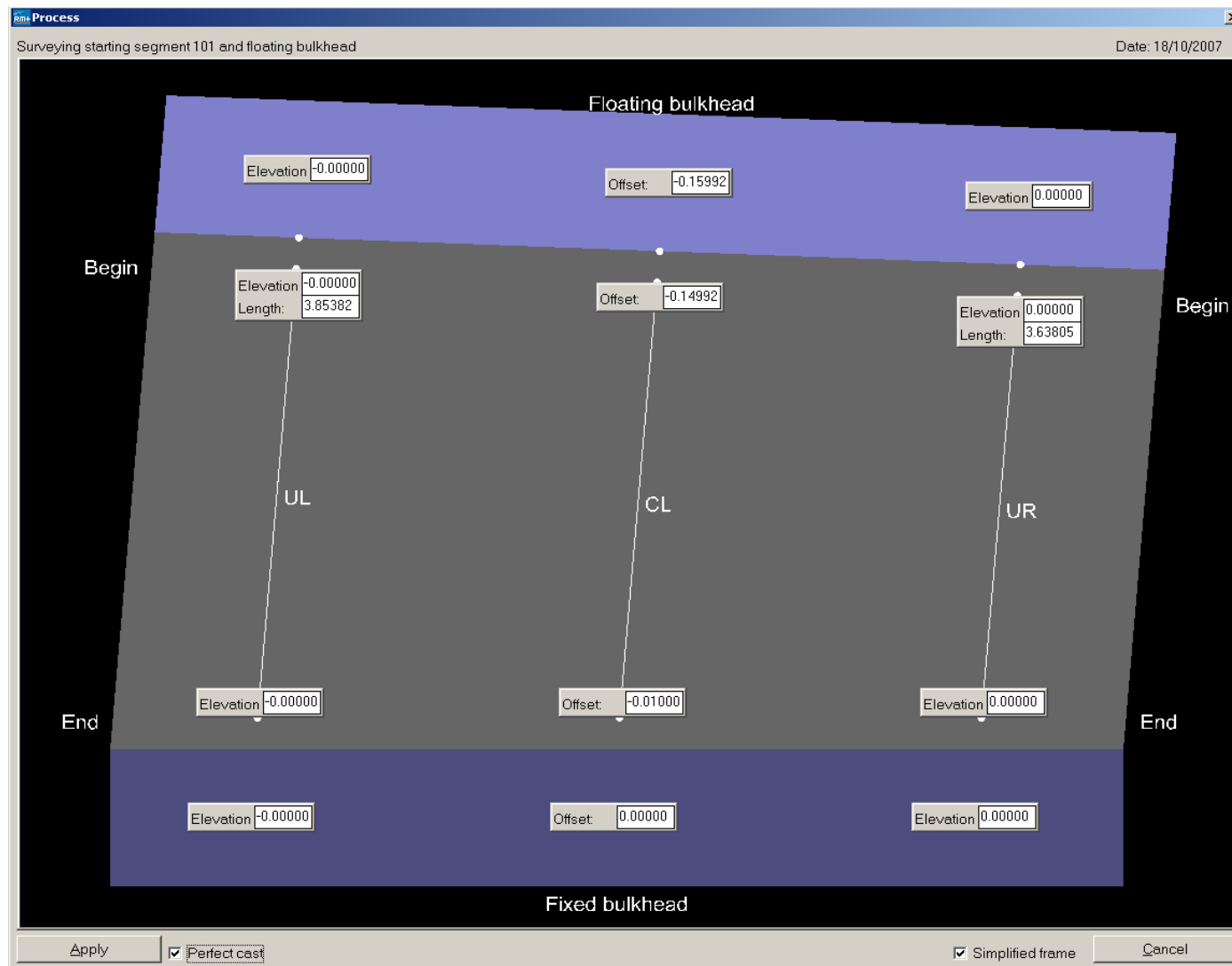


Survey segment

- Survey rivets after casting segment



Writing surveyed values



- RM-cast will then correct the coordinates of next segments depending on the errors in surveyed segment.

Edit Segment Elements

☐ Modify cross section

Cross Section: Deck

From element: 11 <<

To element: 11 >>

Step: 1 All

☐ Modify station ☐ Station at element begin ☒ Element length

Station [m]: 28.987429 Length [m]: 2.598482

☒ Modify segmentation length Length [m]: 1.0000

☐ Absolute ☒ Relative

☒ Modify segmentation type

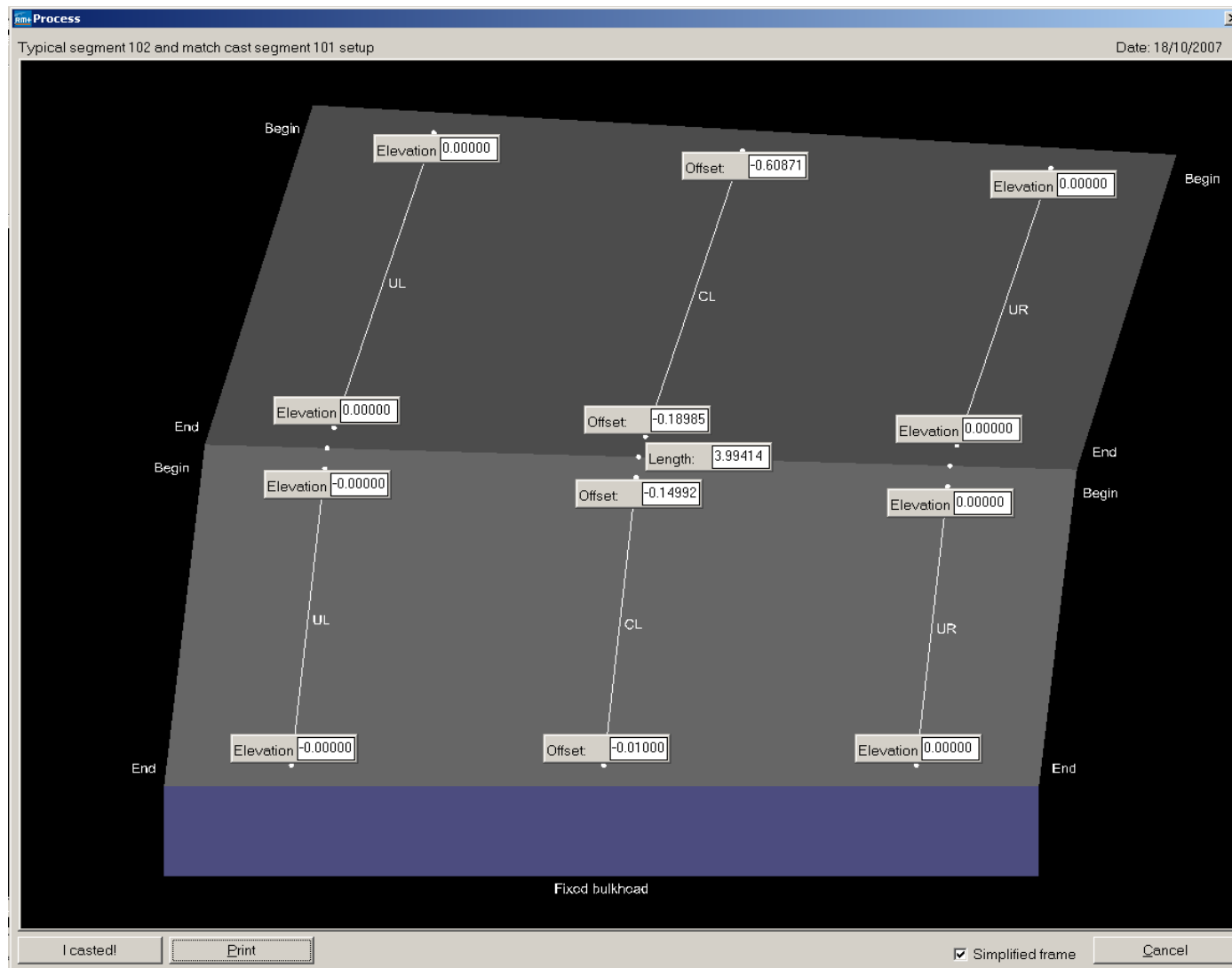
☐ Start ☐ Intermediate ☒ Closure ☐ None

☒ Modify segmentation direction

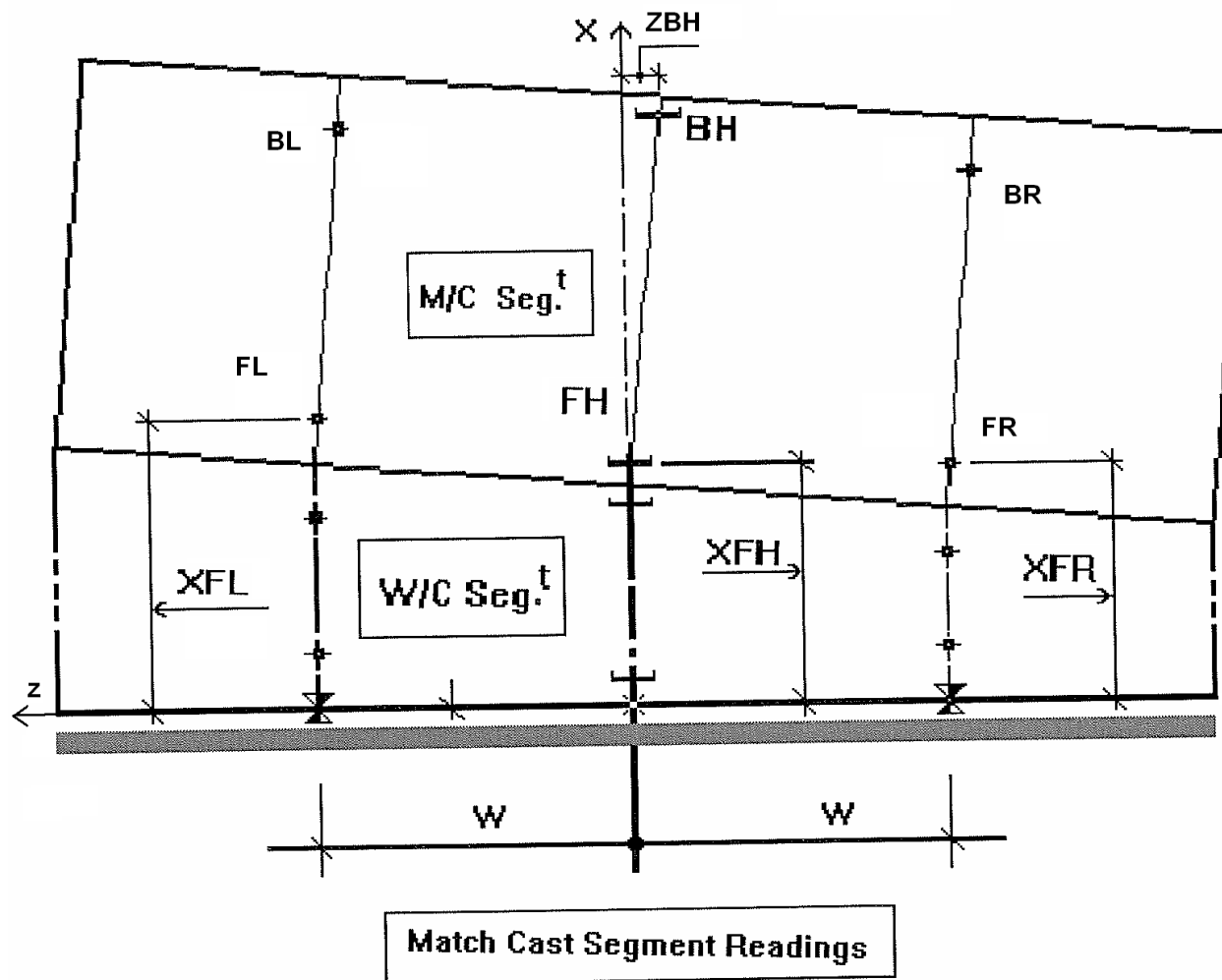
☒ Ascending ☐ Descending

Pointwise Ok Cancel

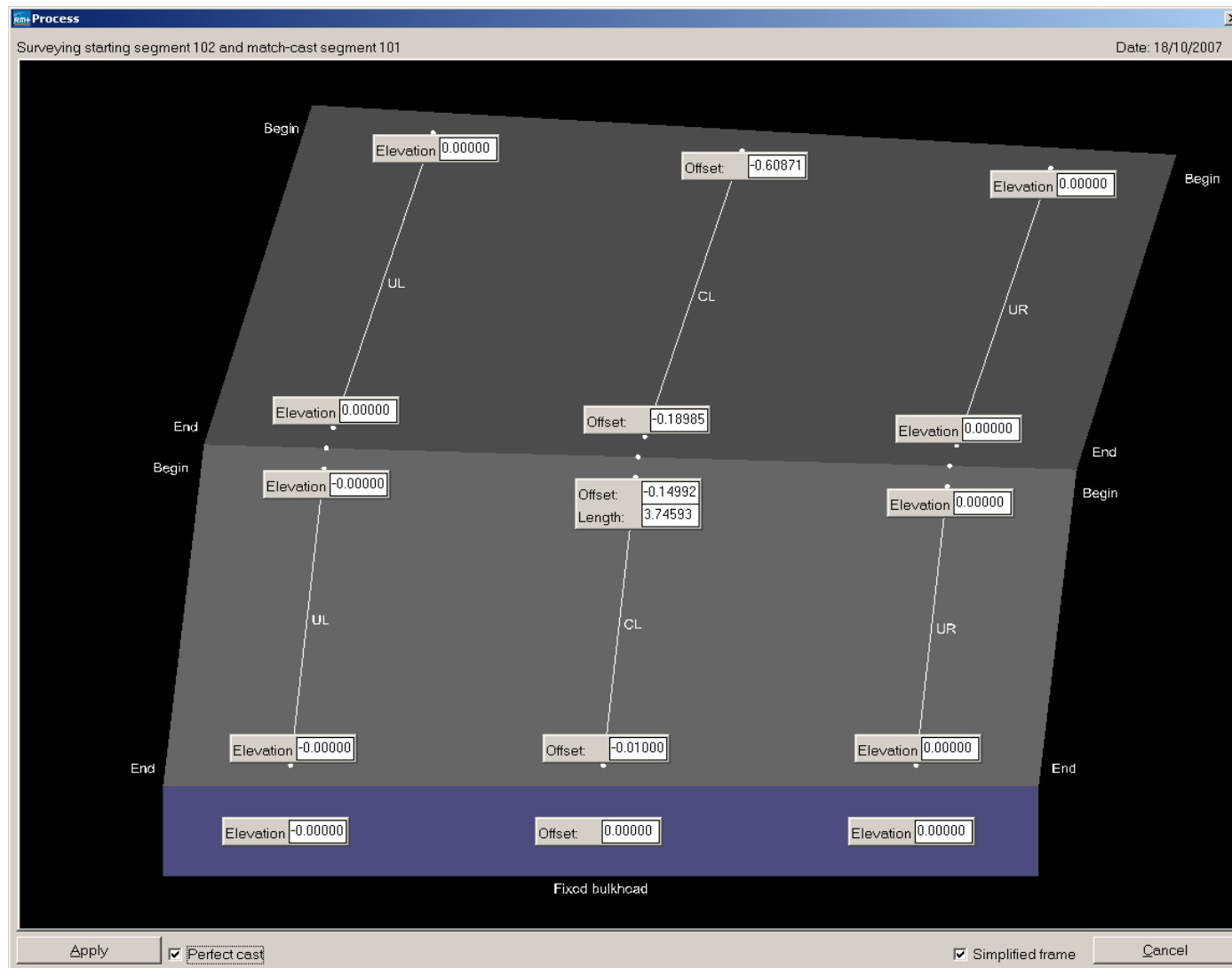
Prepare match-cast segment



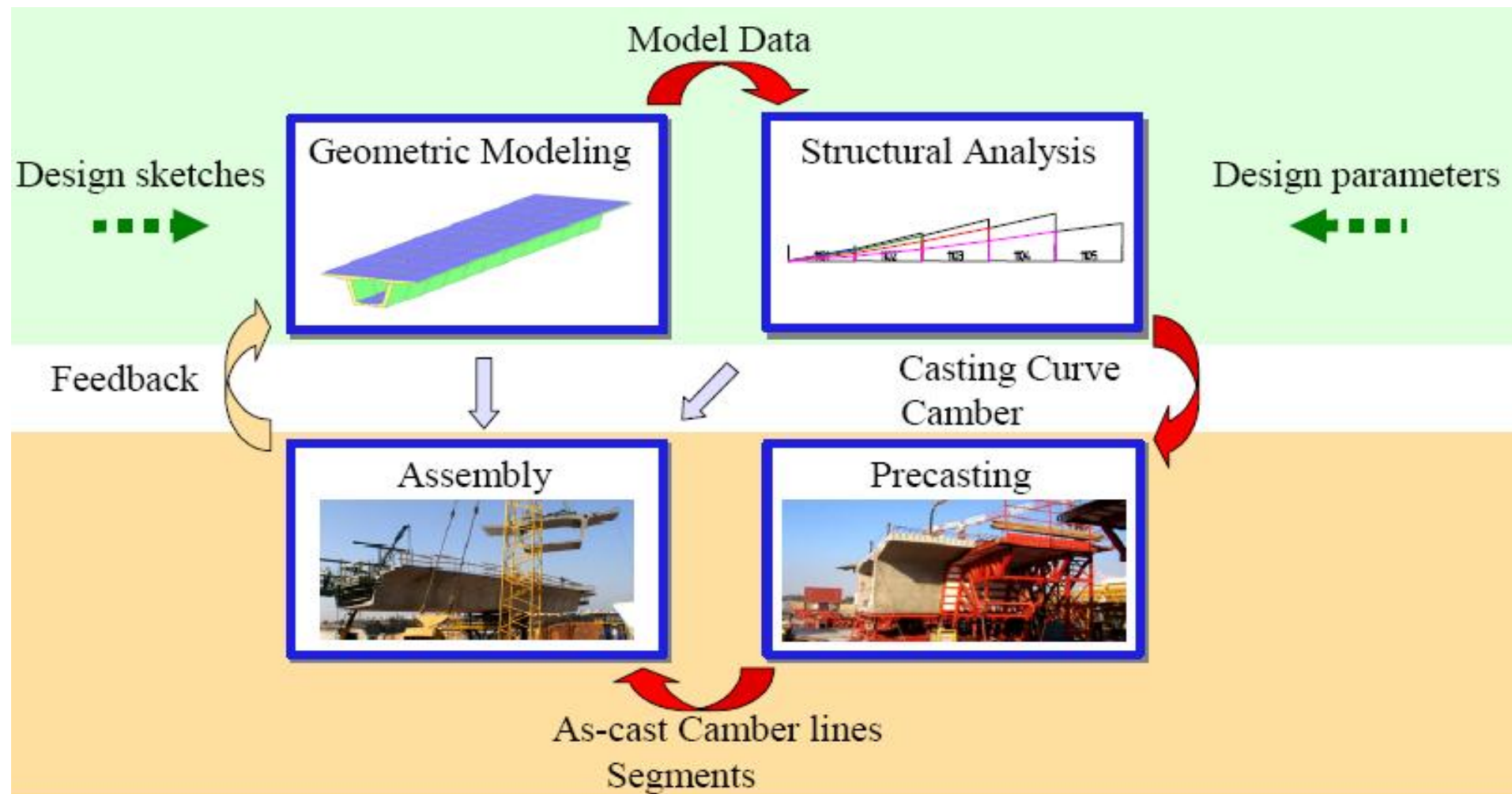
Survey segment



Writing surveyed values

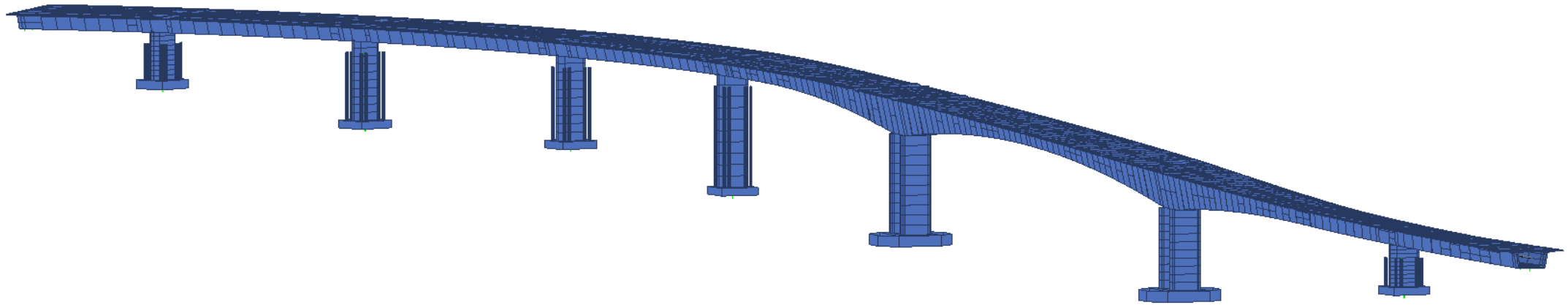


- Repeat this procedure until you complete whole casting set.



Bentley RM Bridge CAST Tool

Conclusions



RM 3D structural model

bridge over the Kanawha River

(Courtesy of Finley Engineering Group, Inc.)

RM Bridge CAST tool



- Balance Cantilever + ABC = Segmental
- Bentley RM Bridge solutions
 - PT, C&S, camber, onsite and shape factory control
 - Cantilever, Pre-camber, ADDCON and Erection Control
- RM Bridge CAST tool
 - updating analysis
 - connecting site modifications to design



Kanawha River

West Virginia

RM Bridge & BrIM Benefits

- Bentley BrIM vision
- Bentley portfolio
- Enhanced GUI
- Intuitive cast-by-cast calculation
- One tool for all





Big I - URS



Bentley RM Bridge Introducing CAST Tool

Questions



Thank you for your attention!

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